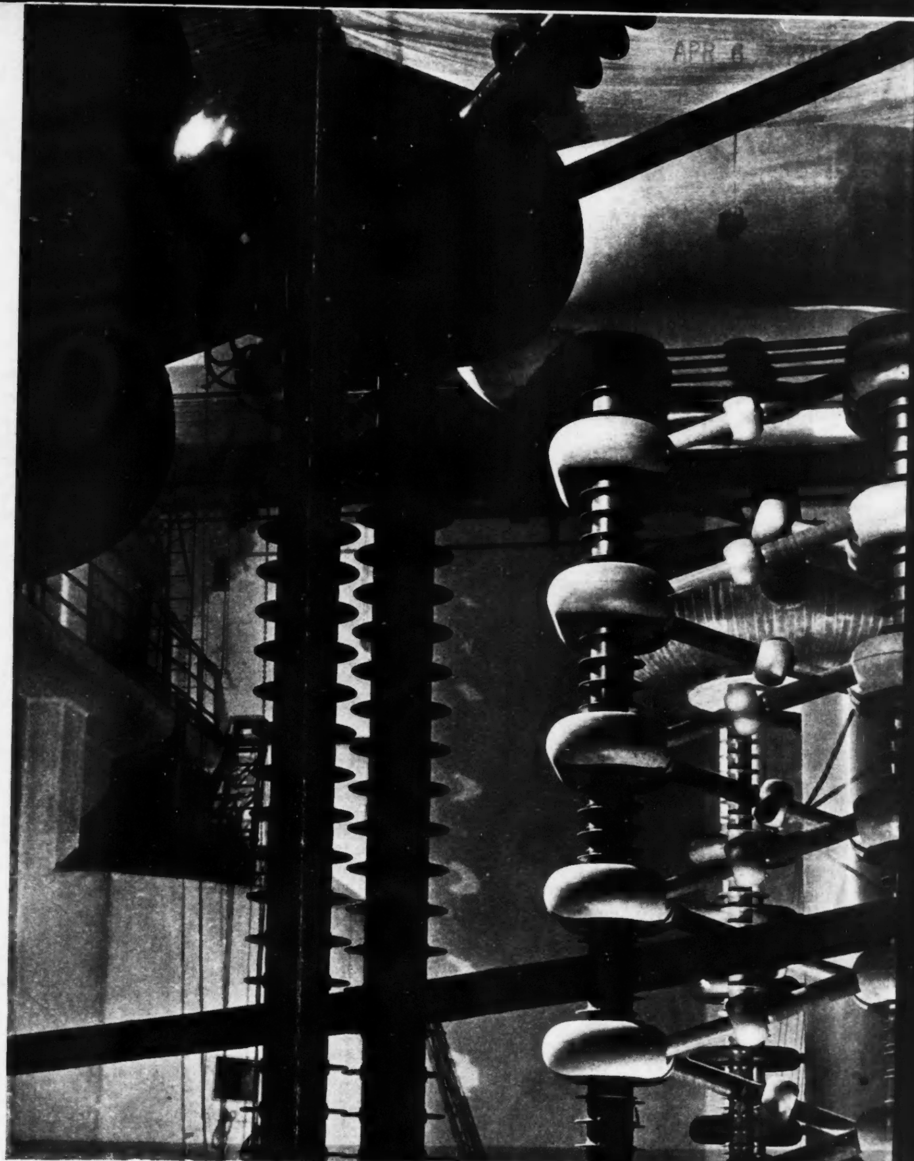
DISCOVERY



The Cavendish Laboratory's million volt accelerator (from the G.B.I. film, "Atomic Physics").

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DISCOVERY

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Editor WILLIAM E. DICK, B.Sc. F.L.S.

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The Progress of Science

The Common Cold

THE recent Cantor lecture by Dr. C. H. Andrewes of the National Institute for Medical Research attracted as much attention in the lay press as any science story since the atomic bomb. He was not talking about anything so spectacular as the atomic bomb, but the news editors of Fleet Street, shrewd judges of what interests the public, singled it out and gave it special prominence. His subject? The common cold—what is, and what is not, known about it. Though readers will have seen accounts of this lecture in the daily press, many points that Dr. Andrewes made went unreported and are worth summarising here.

Firstly it needs to be stressed that the number of useful facts so far collected by scientists on the subject is very small. This is not surprising as it was only recently that intensive research on the problem of the common cold started, principally in Britain and America. The Common Cold Research Unit of the Medical Research Council was not set up until 1946.

There are plenty of obstacles in the path of these research workers. There is, for example, the difficulty of diagnosis. So far it has been impossible to define exactly the common cold and separate it from other infections because there is no convenient experimental animal which can be given colds and there is no simple laboratory test wherewith to test the presence of a cold. What is known definitely is that nasal secretions from a person with a cold, after passage through a fine filter to remove the bacteria, produce a cold when dropped into the nose of a normal person. The cautious conclusion is drawn, therefore, that it is *likely* that a virus (or viruses) causes colds.

Most people think of colds as contagious in much the same way as measles is contagious. But it is just possible that the cold virus may be present in our bodies all the time.

In mice, for instance, there is a whole row of viruses present in the lungs, the gut or the brain, causing no trouble until the balance between host and parasite is disturbed in such a way as will bring the latent infection into the light of day. In man, the fever-blisters which often appear on lips or nose during fever are caused by a virus, that of *herpes simplex*, which is probably there year in and year out and only shows itself when some stimulus, such as a fever, upsets the balance and allows it to become temporarily able to inflict a little damage. In considering how the cold virus causes disease, Dr. Andrewes said its effects may put it in this class of infections rather than along with measles; or perhaps it belongs in an intermediate group.

Colds are commoner in winter than in summer. But why this should be so is as yet unknown. Dr. Andrewes said it is not simply a question of temperature as is evident from American observations. The changing incidence of colds—often as waves of increased prevalence—has been plotted for various North American cities. You might expect that, as lower temperatures were reached, the wave of colds would travel from the northern states, which got cold weather soonest, down southwards. Not at all; the waves occur almost simultaneously from the colder Canadian border down to the Gulf of Mexico. What may have some influence is the occurrence of sudden temperature changes, particularly abnormal ones, and these may precipitate colds more in the summer than in the winter. Some writers have tried to trace an association of colds with humidity and with other meteorological happenings, but without carrying great conviction. Cold weather could, of course, act indirectly by making people crowd together indoors instead of sitting in the park or the garden or, at the worst, in rooms with wide-open windows. Crowding together can, however, hardly be all-important, for in London hundreds of thousands of people must travel daily by train, tube or bus all through the year: and why should colds not spread in tube trains in rush-hours in July?

The lack of a convenient cold-catching animal for use in experiments has already been mentioned. (Chimpanzees can be given colds, but they are most unmanageable beasts and Dr. Andrewes described them as quite useless for cold researches.) In the absence of a suitable experimental animal the research workers have to fall back on the use of human volunteers, on whom the experimental work being done by the Common Cold Research Unit at the Harvard Hospital, Salisbury, depends.

Dr. Andrewes summarised the results so far obtained as follows: "Bacteria-free filtrates of washings from 'cold' sufferers have produced colds in about 50 per cent of subjects. This has happened all through the year, with possibly a rather lower percentage of 'takes' in winter. The time from inoculation to onset has been usually two to three days. We cannot dilute the nasal secretions beyond 1 in 100 and still obtain 'takes'. We can store the active agent for over six months at -76°C. in dry ice and still get 'takes': this has been of great practical value, as we can store our virus thus and keep going back to material of known activity. We can get the virus through a collodion membrane with pores of known size and thus learn that its diameter is somewhere near that of the influenza virus —that is about a ten-thousandth of a millimetre."

British attempts to grow the virus in eggs or in other ways have so far proved unsuccessful. Dr. Andrewes referred to the claim of Pollard and Caplowitz (working in Texas) and of Topping and Atlas (working at the U.S. National Institute of Health) to have cultivated the cold virus in eggs. The apparent discrepancy between the British and American results is probably due to the existence of several different kinds of cold virus. The kind of cold caused by the virus named V14A which Topping and Atlas have isolated is certainly very different from the kind being investigated at Salisbury.

Dr. Andrewes was not optimistic about the chances of preparing an effective cold vaccine. Incidentally it does not appear that infection with a cold virus leaves behind more than a very temporary immunity to the disease. He was more encouraging about the prospects for combating colds (and airborne respiratory infections in general) by 'air hygiene' techniques. At the Harvard Hospital, a Air-Hygiene Unit is collaborating very closely with the cold researchers. The motto of the air hygienists has been 'coughs and sneezes spread diseases'. The doctrine has lately been popularised that minute 'droplet nuclei' are of special importance in spreading such diseases. The larger particles emitted during sneezing fall rather quickly to the ground, but the tinier ones very rapidly lose water by evaporation and thus become so small and light that they can float in the air for an hour or two. These are the 'droplet nuclei' which may still be detected in the air an hour after a sneezer has left a room.

FIG. 1.—Research on the common cold has been handicapped for lack of an experimental animal. Scientists of the Common Cold Research Unit at Salisbury are using human volunteers, one of whom is here seen receiving filtered nasal secretion. This method gives colds to about 50% of the volunteers so treated.

Ultra-violet light and some chemicals are rather effective in destroying these. The larger particles, however, which fall down and are incorporated in dust, may later get re-dispersed into the air, and they are then much harder to kill by the aid of these methods. Some recent evidence suggests that more unpleasant germs get spread from the nose than from the mouth and throat; this leads to the question of whether bacteria and viruses accidentally shaken out of handkerchiefs may not be of tremendous importance. Tests at Salisbury have shown that very many bacteria may thus be shaken out and remain for a time in the air: handkerchiefs from the later stages of a cold are particularly effective germ distributors. Work now in progress suggests the possibility that impregnation of handkerchiefs with a disinfectant (phenyl mercuric bromide seems the most promising) may make them much less dangerous in this respect. This may be important: infected handkerchiefs may be a danger not merely because of what is shaken off them into the air, but because the handling of contaminated handkerchiefs necessarily spreads germs on to the hands and thence on to everything a person touches.

A major difficulty in trying to control the spread of respiratory infections is that all the things Dr. Andrewes mentioned may be important: the germs left in the air after a sneeze, those blown about in dust, those coming off a handkerchief or off your hands, and so tests of preventive measures may yield wholly negative results unless measures against all these vehicles of infection-spread are undertaken at the same time.

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How do Birds Navigate?

A MOST fascinating problem for which students of animal behaviour have long sought a solution is that of explaining satisfactorily how pigeons are able to 'home' over hundreds of miles of unfamiliar territory. Also awaiting explanation is the ability of wild migrant birds to navigate over great distances of featureless oceans and return each year often to the identical nesting site which had been used previously.

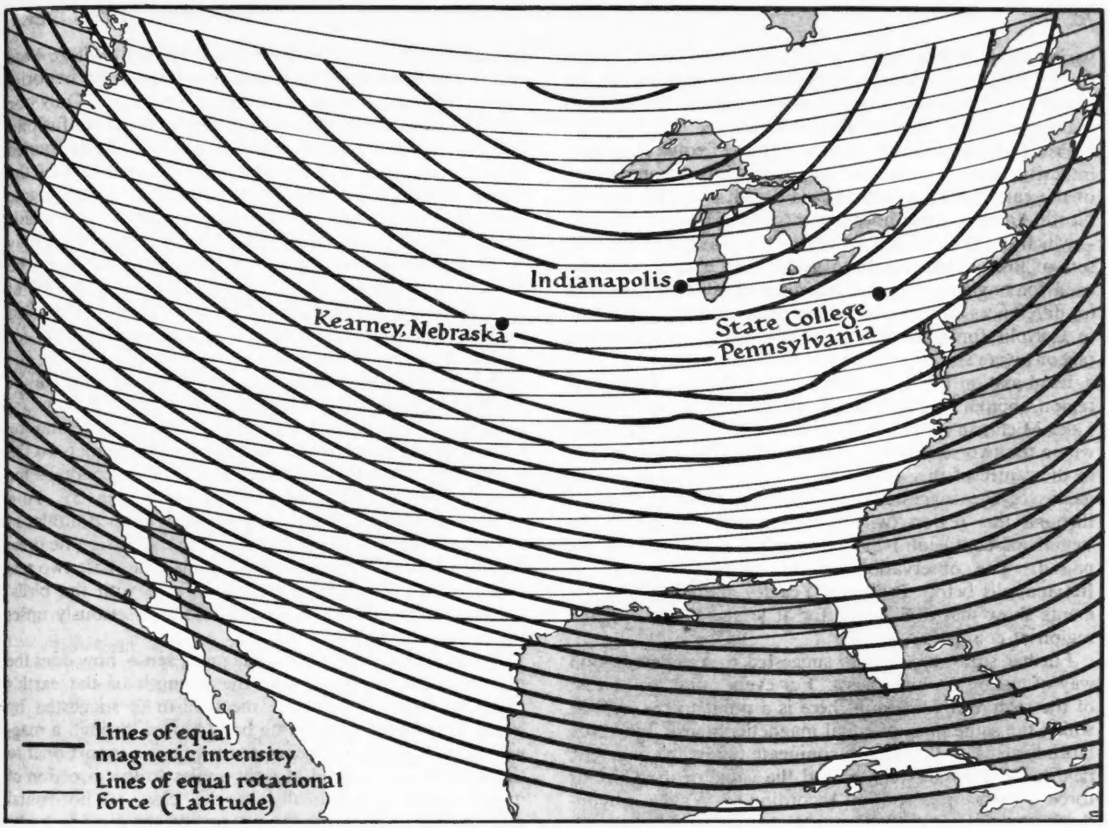

FIG. 2.—The combined effect of the Coriolis force and the magnetic field is exactly the same at Kearney and Pennsylvania State College. Prof. Yeagley found that if pigeons trained to home to Pennyslvania State College were released to the west of the region of confusion (which runs very roughly north and south through Indianapolis) they flew to Kearney; and vice versa

Recently an American physicist, Professor H. L. Yeagley of Pennsylvania State College, has put forward some ideas which seem to explain fairly well the results of a large number of experiments with homing pigeons. The daring hypothesis he puts forward is in its own way at least as stimulating as the explanation involving supersonic echo-sounding, advanced by Griffin and Galambos, to account for the ability of bats to locate obstacles, though his experiments so far are by no means so conclusive as those now classic bat experiments.

It was a consideration of the following facts about homing pigeons which led the professor to formulate his theory.

1. When pigeons are released at the beginning of a homing flight they usually fly in wide circles for a few minutes before moving off in a straight line towards the home loft. After intensive training, however, the birds often sense the correct direction after making only one circle, or part of a circle.

2. They cannot navigate in winds much over 35 m.p.h. and experienced pigeon fanciers avoid winds of over 15 m.p.h.

3. The pigeon's homing ability can be sharpened by training the bird over longer and longer distances; a young bird is first released a mere mile or so from home; the distance is stepped up by stages, being increased from, say, one mile to two, then to four, eight, sixteen and so on. A bird which has been so trained up to, say, 100 miles will home when it is released 200 miles from its home loft. When this fact is considered in conjunction with certain others it becomes apparent that homing pigeons have an exceedingly acute sense of direction.

4. Professor Yeagley also took into account reports that pigeons are confused and unable to pick the right direction for flight when released near powerful radio and radar transmitters.

The professor found his final clue in an article by F. J. Sauertig in the *American Racing Pigeon News* (Nov. 1, 1942), which recorded the failure of pigeons to home to lofts in the neighbourhood of Indianapolis. The significance of this point will emerge later.

Now as long ago as 1882 it had been suggested that pigeons might be sensitive to the strength of the earth's magnetic field, though no proof of this sensitivity was forthcoming at the time. Such sensitivity alone could not provide the bird with a means of navigation. This is obvious when one remembers that a particular magnetic field strength is specific not for a particular point but for all points on a particular line (the field strength is the same all the way along a particular magnetic 'latitude' which forms a rough circle around the magnetic pole).

Another suggestion was that the birds could detect the

variations in the strength of what is called the Coriolis force,* which is a consequence of the earth's revolution on its axis. This Coriolis force varies in strength in a regular manner with the latitude of the detector.

Professor Yeagley noticed that if lines of equal magnetic intensity (actually equal intensity of the vertical component of the earth's magnetic field) are drawn over the map of North America these lines cut across the lines of latitude —which are lines of equal Coriolis force—so that the two sets of lines together form a grid. Such a grid could be used for navigation by an organism capable of detecting (*a*) differences in magnetic field strength and (*b*) differences in Coriolis force strength. The professor suggested that pigeons were sensitive to these two factors.

Examination of the map (Fig. 2) shows that there is a region about 150–200 miles broad and extending through Lake Michigan into Canada and southwards into Florida where the two sets of lines are parallel. Indianapolis falls in the centre of this band. Now if a pigeon navigates by means of the suggested grid one would expect that all through this region (which may fittingly be called the 'region of confusion') the homing faculty would be impaired. The observations made by pigeon racers at Indianapolis before Professor Yeagley started his experiments show that this is true for at least one place in the region of confusion.

Further study of the map suggested to Yeagley a good way of testing his hypothesis. For every point to the east of the region of confusion there is a point to the west at which the same lines of equal magnetic intensity and true latitude cross. At these two conjugate points the magnetic field has the same strength, and the value of the Coriolis force is the same at both. According to Yeagley's hypothesis a pigeon should be unable to distinguish between the two points (unless it could identify the exact locality from visual landmarks and so dispense with the system of grid navigation, a possibility which was easily ruled out by the design of his experiments).

The conjugate point of Pennsylvania State College is near the town of Kearney in Nebraska. These two places are 1100 miles apart. Yeagley found that when birds trained to home to lofts at Pennsylvania State College were released to the west of the region of confusion the majority (six out of eight) homed to lofts near Kearney. (Only one of the eight succeeded in crossing the region of confusion.) Next the reverse procedure was employed. Birds trained by a pigeon racer in Nebraska were released east of the region of confusion and homed towards the conjugate point in Pennsylvania. Further experiments were made which gave support to the hypothesis. (Incidentally it may be noted that experiments on these lines could never be carried out in Great Britain, or even Europe, because of the different configurations of the earth's magnetic field on this side of the Atlantic. The conjugate points for places in Great Britain are in eastern Siberia.)

Before these particular experiments were undertaken Professor Yeagley had satisfied himself that pigeons are sensitive to the earth's magnetic field. This he did by taking trained homers and fastening small magnets to the wings—the magnets were attached to the underside of the wings between the first and second joints (Fig. 3). To a control set of birds he attached pieces of copper similar in shape and weight to the magnets. The conclusion he drew from the results of homing experiments with these two sets of birds was that the magnets interfered with the birds' reaction to the earth's magnetic field and seriously upset their ability to navigate.

Assuming the pigeon has a magnetic sense, how does the pigeon detect and 'measure' the strength of the earth's magnetic field? A possible mechanism is suggested by Yeagley. When a conducting body moves through a magnetic field a voltage is generated which is proportional to the strength of the field at right-angles to the direction of motion—that is, vertically in the case of horizontal motion—and to the speed and size of the moving body. For a pigeon flying at 40 miles an hour this voltage would be of the micro-volt order, and might make itself felt at a number of places in the bird's nervous system.

That it is the Coriolis force which gives the bird its sense of latitude is the belief of Professor Yeagley and of Professor G. Ising, a distinguished Swedish geophysicist who recently independently made the same suggestion. Professor Ising suggests that the bird detects the Coriolis force on the liquid in the semi-circular canals which form part of the structure of the inner ear. (This view has been questioned by W. H. Thorpe and D. H. Wilkinson of Cambridge University on physiological grounds.)

An alternative explanation for the bird's awareness of latitude is provided by another hypothesis which suggests that it can appreciate differences in the gravitational force, which also varies with latitude.

At the moment Yeagley's ideas are by no means proved, but they are certain to be followed up and to stimulate other workers to check his experiments and results, and to devise others. This should lead to some fruitful collaboration between physicists and biologists.

* This force takes its name from a French scientist called Coriolis who first explained why an object moving above the earth is deflected relative to the surface of the rotating globe. The deflection is to the right in the northern hemisphere and to the left in the southern.

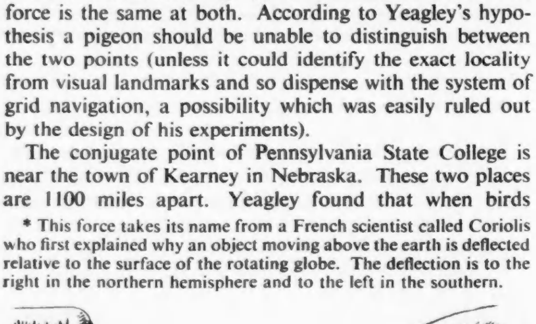

FIG. 3.—This shows where the magnets were attached to the pigeon's wings in Yeagley's experiments that demonstrated sensitivity to magnetism.

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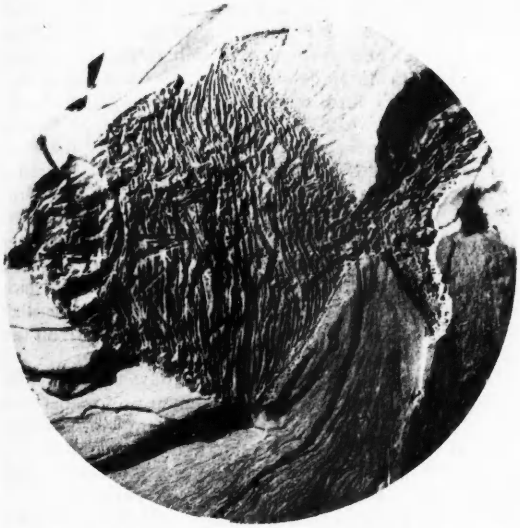
A valuable survey of the literature dealing with the sensory basis of bird navigation has been published by D. R. Griffin in *Quarterly Review of Biology* (1944).

THIS IS THE KIND OF FOSSIL THE SCIENTISTS HOPE THE MINERS WILL SEND—



This fossil fish (about three-quarters natural size) typifies the kind which the University College palaeontologists hope to get from miners in response to Prof. Haldane's appeal. This specimen of *Cheirodus* belonging to the extinct group of Palaeoniscids, was found in N. Staffordshire in black shale. The smooth, fine-grained surface seen towards the bottom right-hand corner is typical of black shale in which such fossils are most abundant. Miners are more likely to find parts rather than whole fossils; both are welcome and should be sent to Professor J. B. S. Haldane, University College, London, W.C.1, together with a note of exact place of finding.

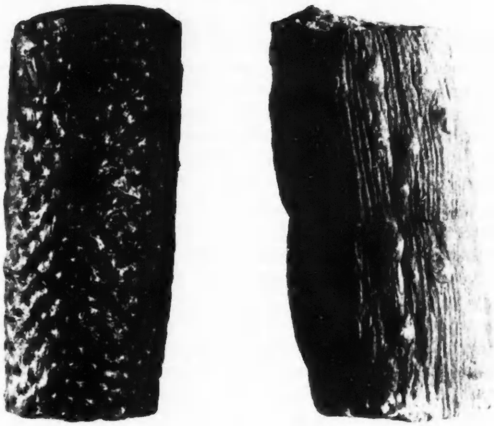
Research and Everyman

"POPULAR science is almost as widely divorced from operative science as is popular music from classical music. The results of science more or less accurately or sensationally reproduced do get through, but piecemeal and leaving behind the whole method and spirit of science." So wrote Professor Bernal in *The Social Function of Science*. There have perhaps been some improvements since then, but that comment is still largely justified. Books, articles and lectures alone teach little of science as a method of investigation; it is only by participation in the investigation that the real nature of scientific work and method can be learnt.

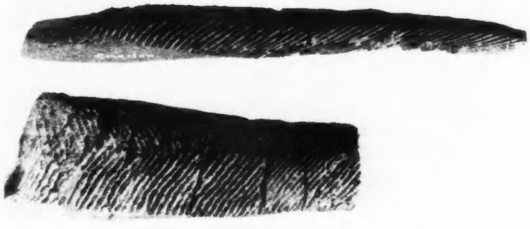
In spite of the growing specialisation and professionalism of science, there are still vast fields in which large numbers of people can help in research, provided they are given appropriate advice in simple terms. They can do so, not only with benefit to themselves in learning the spirit of science, but also with considerable benefit to the advance of science, by collecting certain types of data or material on a scale which is impossible for the comparatively small body of professional scientists.

Professor J. B. S. Haldane has recently demonstrated this in one particular case. The common fossils in our coal-bearing strata which are of interest to the geologist have been fairly extensively investigated. But, in this country at least, comparatively little attention has been given to the rarer vertebrate fossils in the same strata which are required for palaeontological work. Haldane's colleagues, K. A. Kermack and W. G. Kühne, wanted to undertake research in this direction, and they immediately came up against the problem of collecting this very rare material. Only a mass search could be effective, and so Haldane has taken the bold step of writing an article in *Coal*, the magazine of the National Coal Board, appealing to miners to help by sending him fossil finds, accompanied by descriptions of the circumstances of finding. He offers moderate monetary rewards, but we feel sure that the zest of helping in research will be at least as great an incentive as the financial one. In the *Daily Worker* for January 19, Haldane was able to report that he had already received several parcels of fossils. They do not, as it happens, contain anything of great value—but after all it is hardly to be expected that more than an occasional find will prove important. (Those living outside the coalfields cannot help appreciably in these researches, as Kermack and Kühne

—THESE KINDS THEY DON'T WANT



The three specimens shown in this column, all of them at about half natural size, were sent to Prof. Haldane by miners. (*Left*).—A layman might well mistake this for part of a fish. Actually it is a bit of the trunk of a giant clubmoss from Glamorgan. (*Right*).—Again not a fossil fish, but a horse-tail (*Calamites*). These plant remains, unlike fossils of fish and amphibians, separate readily from the adhering rock.



These are fish remains, but not of interest to Haldane and his colleagues. They are spines of large shark-like fish, *Gyracanthus*, and are not uncommon.

want to find out the exact location of seams rich in fossil fish of a certain kind. Such fossils do turn up in coal merchants' yards, and you may even find them in your own coal bin: but stray specimens from those sources should *not* be sent to Haldane!)

Now what will the miner learn by searching for fossils? Probably little at first. But if the search for fossils becomes popular, miners will soon discover that they can do it more successfully when they take the trouble to learn some palaeontology from text-books. They will then reach the point at which they are using existing knowledge as a guide to the search for more knowledge—and that, surely, is one of the main features of the scientific method.

Of course, there are many fields of science in which there seems to be no possibility of enlisting amateur help—mathematics and almost all of physics and chemistry. Yet the possibilities are wide. Even in nuclear physics it has been found possible to enlist the help of amateurs. Dr. C. F. Powell and his colleagues, at Bristol University, have organised such assistance, and a number of volunteers are now helping him by searching for tracks made by cosmic rays and other particles in photographic plates. Dr. E. P. George, of Birkbeck College, is also using amateurs to help him with his researches in the same field.

Ecological studies of importance have from time to time been carried out by bands of schoolboys and by amateur natural history societies. There are clearly many problems, concerned with counting populations, observing migrations, and the like, in which mass observation could provide very important data. And the Council for the Promotion of Field Studies (see DISCOVERY, April 1945, page 127) provides one possible means by which such studies might be organised.

Doubtless, if scientists were to think seriously about how they could make use of mass help, they would discover many more such cases.

In the past DISCOVERY *has several times published appeals from scientists seeking such help, and our columns are always open to any scientist who needs to go beyond the borders of the professional scientific community to obtain assistants.*

If such schemes are to be successful, the scientist will have to develop an explanatory technique of a higher standard than that which occurs in present-day 'popular science'. He will have to learn how to explain to somebody without special training just what he wants done. And that is not easy. Even Haldane had to admit, on the basis of the first few sets of fossils sent to him, that he had not made himself sufficiently clear. Perhaps there will emerge from this a new form of popular science writing—books and articles in which the main emphasis is on *how to observe* this, that or the other thing. Books of that type are conspicuously lacking in modern popular science literature (with a few exceptions in subjects like bird-watching); but the very words 'how to observe' remind us that they were more common a century ago, an excellent example being De La Beche's *How to Observe: Geology.* Here we find sketched a large number of the problems which specially concerned the geologist of the 1830's, together with very luminous instructions on how the layman can accumulate data which will help in their solution.

In those much less professionalised days of science, the distinction between scientist and layman was vaguer than today; and even the comparatively rare professional scientist, when he needed help, had to turn not to a convenient Ph.D. student but to some intelligent and enthusiastic amateur, who might be a miner, surveyor, engineering contractor or gentleman of leisure. In those times the scientist had to know how to tell a layman what to look for. And if there is now going to be a growth of popular participation in research, the scientist may well have to study the history of the mid-nineteenth century to discover first how the liaison of scientist and layman was carried out.

Building Houses with a Spray Gun

THE new building material called Pyrok which is just coming into use resulted from two years' research in a group of buildings on a bombed site in North London. A surfacing material which can be sprayed up to 8 inches thick on to wire mesh, and which sets within fifty minutes, it is made from Portland cement, lime and vermiculite—the latter being a type of mica found abundantly within the British Commonwealth, particularly in South Africa

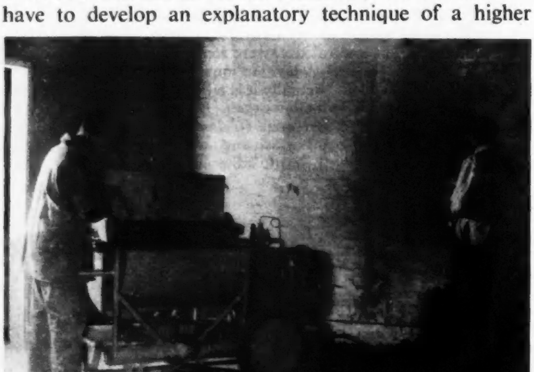
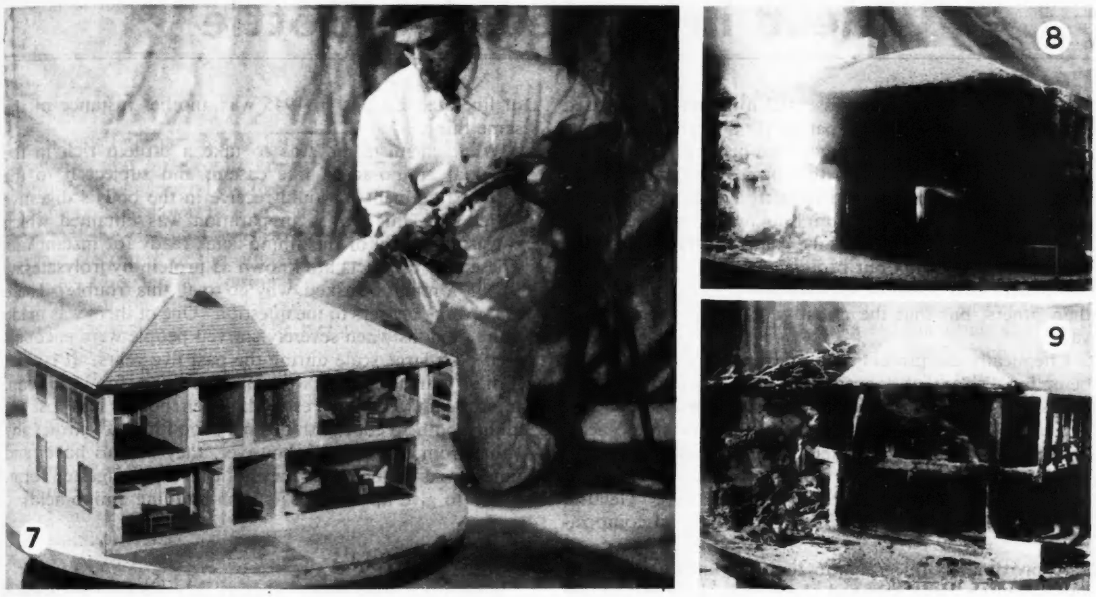


FIG. 5 (*left*).—The combined mixer and air compressor used for spraying pyrok, which is made by mixing lime, cement and vermiculite in the tank. FIG. 6 (*right*).—Technique of building a pyrok wall. Two sheets of wire mesh with a space between are sprayed with the mixture to the necessary thickness—up to eight inches is possible.



DEMONSTRATION OF FIRE RESISTANCE OF PYROK-COATED MATERIAL.

FIG. 7.—A wooden model house, one half of which is sprayed inside and out with a layer of pyrok one-sixteenth of an inch thick. FIG. 8.—The model is soaked with petrol and set on fire. FIG. 9.—After the fire. The untreated side has collapsed, completely gutted. The pyrok-treated side stands undamaged. (*COI photographs.*)

and Kenya. In colour it looks much the same as ordinary plaster. (Figs. 5 and 6.)

Professor J. D. Bernal, late chairman of the Scientific Advisory Committee to the Ministry of Works, has reported on this material: "This is the most promising step I have seen in building technique. The combination of Pyrok with wire mesh may well mean new shapes for our homes with their main shells completed at a fraction of the present-day cost."

The material has been applied to such surfaces as steel, iron, asbestos-cement sheeting, galvanised sheeting, brickwork, concrete, timber, clay blocks, wood and cork. It can be applied both to vertical and horizontal surfaces, and can be blown on to give any required thickness in one operation. There is no need to wait for one coat to dry before adding the next, thus reducing the time necessary to attain the desired thickness. The surface resembles roughcast when blown on by the gun, but a comparatively smooth surface can be obtained by a special vibrating screeding bar. The final smooth finish is achieved by the use of a vibrating finishing tool.

It seems to be free from the common fault of normal plaster in that it does not crack, owing to the resilient action of the vermiculite. Moreover, it takes nails or screws and can be cut with an ordinary saw. It is waterproof and in its normal state is absorbent, so that no condensation or 'sweating' occurs in the most 'muggy' weather. There is no difficulty in applying the usual paints and distempers to a Pyrok wall.

An enthusiastic report on this new material appeared some months ago in the *Journal of the Royal Institute of British Architects* (October 1947). Here are some of the main points of that report:

One characteristic is the extremely high fusing point of vermiculite, which is obviously of great importance for fire-resisting purposes (Figs. 7–9). In the course of experiments a steel joist was filled between the flanges with Pyrok to a thickness of some $2\frac{1}{2}$ in. It was applied straight on the base metal (for no bracketing or mesh is required) and a blow-lamp was then directed at it for $4\frac{1}{2}$ hours; at the end of that time the material was undamaged and only just a perceptible warmth could be felt in the flange on the opposite side.

This undoubtedly introduces a new technique in fire protection of buildings, as steel stanchions and joists can be completely encased in Pyrok. Even when applied to timber, the protective qualities are similar. A wood board was coated to a thickness of just under $\frac{1}{8}$ in. and then subjected to the flame from a blow-lamp for $2\frac{1}{2}$ hours. The Pyrok surface remained in place and the wood beneath was found to be only charred.

Other tests to which the material was submitted included that of weather resistance. "A brick wall coated with the material was left exposed to the rigours of last winter; not content with that, the patentee sprayed the coating with water and let ice form on it, and it was not affected. In another test a steaming machine was allowed to discharge water vapour to the underside of a panel coated with the material, and even after an application lasting several minutes no condensation was observable."

At the moment the limited imports of vermiculite is restricting the output of this material in Britain.

Meat in a Medicine Bottle

WHAT is your taste in that essential nitrogen-food classed as protein—a juicy chop, perhaps? Slightly underdone beef, cold chicken, a boiled egg, fried herrings? Or do you prefer it from the garden in the form of peas and beans? Luckily nature has provided us with a wide choice. The majority of us eat protein from both animal and vegetable sources. Which, science tells us, is a good thing. In other words, we should mix our proteins. The reason for this is not merely that certain foods contain a larger proportion than others, but that the nutritive value of protein itself varies.

Chemically the protein molecules are very complicated, being built up of substances called amino-acids. Were we to take the large molecules to pieces, so to speak, we should end up with varying proportions of different amino-acids according to the type of protein we were examining. Beef, for example, would always contain the same particular amino-acids combined in certain proportions. Gelatin, on the other hand, would have its own special composition.

Approximately thirty amino-acids are known at present and scientists have grouped them into those which the body cannot manage without, and those which it can. About ten of the former class have been recognised, and if one of them is missing from the diet our health suffers. The human machine can manufacture the non-essential amino-acids from other foodstuffs if they are not present in the diet, but for its supply of the essential ones it depends entirely upon protein given as food. That is why a mixed protein diet is necessary—to ensure that we get all the amino-acids we need and in sufficient amount.

But what is the significance of these substances? It can best be illustrated by examining the fate of your favourite protein food—the slightly underdone beef, or whatever it may be—once it gets into the digestive system. By the time the various gastric juices have finished their work it will have been split up into its amino-acids. These are absorbed by the bloodstream and dispatched to the liver, the body's main protein factory, and built up into protein again. This protein is the solid stuff of our flesh and is present in body fluids such as blood and even, in small amounts, in our hair, finger- and toe-nails, teeth, and bones.

Pre-digested Protein

The milk-protein, casein, is just about perfect because it contains all the essential amino-acids combined in just the right proportions for our needs. That is why the chief ingredient of many patent build-you-up foods is either milk itself in some form or other, or powdered casein. But even these preparations have to be digested before they can do their good work. And whereas protein feeding in normal or near-normal health is a simple enough matter, in cases of serious ill-health—certain types, especially—it can present many problems to doctors.

Or rather, it did—prior to the Bengal famine of 1943 when new ways of giving protein were first applied on a large scale. The F-food distributed to the starving peoples of liberated Europe in 1945 was another instance of the same thing.

What chemists did was to take a protein rich in the essential amino-acids, like casein, and subject it to the sort of treatment it would receive in the body's digestive system. In this way a preparation was obtained which consisted chiefly of the amino-acids ready for instant use. These new products are known as protein hydrolysates.

But, it might be asked, why go to all this trouble? There are several answers to the question. One of them was made quite obvious when severely starved people were encountered on a large scale during the past five years. It is, that if these living skeletons were given ordinary food too soon, rapid death generally resulted. Their bodies had lost the ability both to cope with ordinary food and to extract any value from it. Protein, however, they had to have, and quickly. As hydrolysates they got it in a pre-digested form, ready to give up at once its flesh-building amino-acids.

Use in Hospitals

It was not long before British manufacturing chemists prepared and marketed protein hydrolysates under various proprietary names, and for several years now they have been widely used in our hospitals to treat patients whose special need of protein cannot adequately be met in the ordinary way.

When, for instance, flesh has been extensively destroyed or damaged, such as happens in cases of severe burns, a plentiful supply of the right protein food is vitally necessary to bring about repair or renewal of tissue. But the patient's condition may render it impossible for sufficient protein to be given him in the ordinary way as solid food such as meat and fish. His digestive system might, in any case, be too weak to deal with it. This patient can, however, now be given protein hydrolysates, either as a drink or by injection, and so receive the tissue-building amino-acids his body so urgently requires.

Another point of interest concerning these burns cases is this: Experts have estimated that some of them need the equivalent of between two and three pounds of meat daily in order to make good their loss of nitrogen. Obviously, quite apart from the rationing problem, the average active person in good health would find the consumption of so large an amount somewhat too much for him to tackle. What, then, could be expected of a shocked and very ill patient lying in a hospital bed? Again, protein hydrolysates do the trick, for the patient can be given the equivalent of a fair-sized week-end joint as often as may be necessary. He will not have to digest it: in fact, he can have it run direct into his bloodstream through an intravenous needle, if his condition requires it.

Cases of malnutrition, severe wounds—these and many others all respond to protein hydrolysate feeding. More and more are these amino-acid preparations being used in our hospitals. Thus, from out of the miseries of the Bengal famine and the horrors of war has come a new and valuable ally in man's fight against ill-health.

W. L. SUMMERFIELD, PH.C.

The Discoverer of Insulin

GEOFFREY H. BOURNE, D.Phil., D.Sc.

On Sunday, February 23, 1941, the news was flashed round the world that an aircraft bound for England with the Nobel Prize-winner and discoverer of insulin, Sir Frederick Banting on board, was missing. On February 24 there was news that the plane had crashed in Newfoundland, and in the late afternoon of the same day the Honourable J. L. Ralston, Minister of National Defence, informed the Assembly of the Canadian House of Commons that its leading scientist was dead. The melancholy tidings soon winged their way round the world and scientists and lay people, who remembered the health and happiness which the work initiated by Sir Frederick Banting had brought to numberless diabetics, deplored the accident which had cost him his life.

Among the memorials to Banting and his work must be accounted the biography,* written by his friend and colleague Dr. Lloyd Stevenson. The biographer has written his account with sympathy and understanding, not hesitating to draw attention to Banting's faults but phrasing his words so that the faults serve only to highlight the scientist's manifold achievements. Starting way back in Banting's early childhood he takes us through his experiences as a medical student, as a soldier in the first world war, through his worries and anxieties during the isolation of active extracts of the pancreas, to the pinnacle of his fame, and after to his untimely death.

Sir Frederick Banting (1891–1941).

Banting, we find, was born on November 14, 1891, in the town of Alliston in Ontario, Canada. He was the youngest of five children, of which four were boys and one a girl. His father was of English stock and his mother Scottish in descent; they had a farm near Alliston, and it was here that Frederick Grant Banting was born.

His early years at his parents' farm were happy, but Banting was inclined to be rather a grave and thoughtful child and not subject to the same unrestrained jollity as his brothers and sisters. At school he worked conscientiously but did not excel at his studies; languages seemed particularly difficult to him. Of his school work Dr. Stevenson says, "His method was not a quick and shallow assimilation exhibited in fluent recital from his books, but a slow mulling over in his mind of everything that was offered him for study. Some of it he retained; some of it he forgot; most of it, at any rate, he thought about." Banting early exhibited some artistic ability, and his first attempts to sketch trees and farm animals were soon followed by pen and ink cartoons in imitation of those he saw in magazines. He even turned his hand to painting in oils. Later in life it became his great relaxation, and many were the trips he made into the interior of Canada with palette and canvas.

An incident of his childhood fixed in his mind the idea of taking up a medical career. He was watching, on his way home from school, two men shingling a house. As he watched, the scaffolding on which they were standing broke and the men fell to the ground. They were too injured to rise and Banting ran for a doctor. Watching him minister to these injured men decided the scientist-to-be that "the greatest service in life is that of the medical profession". His parents, however, had other views and decided that he should be trained for the Church. He was duly sent off to study for the clergy, but rapidly became restless as his desire to take a medical course became more and more strong and his interest in divinity dwindled. Finally he approached his parents and put his problem to them, and they, though such a change meant a great strain on their financial resources, readily gave their consent when they realised that their youngest child really knew his own mind.

An Average Student

As a medical student, Banting again showed little more than average ability. He kept somewhere near the middle of his class, but he had an interest in his subject which extended beyond the lecture room and the laboratory. For one thing he was one of the few who possessed their own microscopes. In physiology and pharmacology his class experiments interested him so much that he frequently failed to break off for lunch, an attitude which his fellow students did not understand. It is recorded that the Professor of Biochemistry (A. B. McCallum) in a lecture to Banting's class said that the secret of the body's ability to mobilise sugar probably lay in the 'islets of Langerhans' of the pancreas and that possibly a member of the class might cover himself with honour and glory by discovering the secret.

Banting set his heart on becoming an orthopaedic surgeon but before his medical course was completed the 1914–18 war broke out. He wanted to enlist immediately in the army as a private but was constrained to complete his medical course. This he did, but once qualified, he immediately joined (along with sixty-six of his class mates) the Canadian Army Medical Corps. Within a short time he was posted to France. There he worked at advanced first-aid posts where his coolness under fire attracted attention. He was wounded and won the Military Cross. After the war Banting returned to Toronto (where he had done his medical course) and pursued his orthopaedic studies for a time and then went to London Ontario, where he set up in practice. Patients were not, however, plentiful, and Banting whiled away spare time by reading accounts of medical research. On October 30, 1920, he had the great idea which changed the course of his life. He read in one scientific journal an account of an

*'*Sir Frederick Banting*, by Dr. Lloyd Stevenson. Heinemann, London, 1947, pp. 446, 25*s*.

experiment in which the duct of the pancreas* of an animal had been tied; that part of the pancreas which produced the digestive enzymes degenerated, but small islets of tissue known as the 'islets of Langerhans' (because of their discovery by Paul Langerhans many years before in 1869) were unaffected. The animal did not develop diabetes. Yet it was well known to Banting that if the whole of the pancreas was removed from an animal it rapidly developed diabetes, lapsed into a coma and died. He knew that various people had tried to make extracts from the pancreas to inject into diabetics or to give them to drink, but none of these extracts had been any good. It seemed to him that in making an extract of the pancreas some of the digestive substances in one part of the organ might have destroyed the active substance in the islets of Langerhans. Suppose he tied off the pancreatic duct of the animal, let the digestive part of the gland degenerate and made an extract from the tissue which remained? It seemed a good idea, and he determined to do something about it.

One should perhaps divert here from the story to say something about diabetes. Sugar when it is absorbed into the blood-stream from the intestine is transported to the liver where it is stored. The sugar in the main blood stream of the body fluctuates within a fairly narrow margin. A number of substances affect the level of sugar in the blood, for example adrenalin, secreted by the medulla of the adrenal gland, can cause a considerable increase in the amount present. However, this happens only under conditions of stress or emotion and the day-to-day regulation of the level of blood sugar is the work of the chemical hormone, insulin, which is secreted by the islets of Langerhans in the pancreas. If something goes wrong with the production of insulin from the islets—often due to degeneration (from causes not fully known) of the cells composing the islets—then the level of sugar in the blood rises to danger level. The tissues of the body then seem to melt away, the affected person rapidly loses weight, becomes emaciated, lapses into a diabetic coma and dies. While these clinical changes have been taking place, there has been so much sugar in the blood that it has been filtering through the kidneys into the urine. The urine normally contains no, or only transient traces of, sugar. It is the excessive excretion of sugar in the urine that first leads a physician to suspect diabetes, but the diagnosis is not confirmed until an estimation of the level of sugar in the blood is made. If it is significantly higher than normal then the case is almost certainly one of diabetes. Such a person, formerly doomed to death, can now be restored to a full life and health with the aid of insulin.†

Such was the disease which Banting set out as a young, recently qualified, medical man, unskilled in medicine and unversed in the methods of science, to solve.

The Classic Researches at Toronto

Banting gave up his ideas of a medical practice and went to Toronto University where he approached Professor J. J. R. McLeod, the Professor of Physiology and asked for accommodation and facilities to work on the subject. If Banting had been fully conversant with the discouraging and frustrating literature on diabetes he would never have had the temerity to tackle the problem at all, as he himself later admitted. Professor McLeod had a much better acquaintance with it and was at first not anxious to let such a raw recruit throw himself into such a difficult problem with so little chance of success. However, he finally gave in, and Banting commenced work on his problem on May 16, 1921. A member of the senior physiology class, C. H. Best, was appointed to work with him. They were given ten dogs as experimental animals and eight weeks to carry out their experiments. The first step was for Banting to tie the pancreatic ducts of a number of dogs, and to leave them for some weeks while the digestive part of the gland degenerated. They had many initial disappointments; they found it difficult to get the right pressure on the ligatures tying off the ducts, they found it difficult to remove the whole pancreas from dogs and so cause diabetes, but in the end they perfected their technique, and by July 27 they had a dog available which was in a diabetic condition, due to the removal of its pancreas, and they had another which had had the duct of its pancreas tied and in which the digestive part of the gland should have degenerated leaving the islet tissue more or less intact. They killed the duct-tied dog, chilled its pancreas (to stop degeneration) and ground it up with salt and water. The extract was filtered, and five cubic centimetres of it were injected into the diabetic dog. They removed periodical samples of blood from the animal and estimated the amount of sugar. The amount of sugar fell progressively to normal.

This was their first success and one can well picture their excitement. Then came sobering thoughts, the possibilities of mistake, the chance that this might be a non-specific effect and that other tissues might show it; and so more and more confirmatory experiments were planned, and when these were completed they realised that their first result was correct and that in fact they had made the first active extract of the pancreas. They found that although injections of the extract reduced the blood sugar in diabetic dogs, after a time the sugar content rose again and it was necessary to inject again. Insulin was in fact not a cure for diabetes, but the disease could be controlled by its use.

This was a beginning, and though of scientific interest was not yet of practical value to human diabetics, because it was a practical impossibility to produce enough extract from pancreases obtained by the method of ligaturing the

* The pancreas is colloquially known as the 'sweetbread' and is situated between the stomach and the first part of the intestine (duodenum).

† The diabetics keep the level of sugar in their blood at normal level by periodical injections of insulin but they need, too, to take a diet of known calorie intake. If they inject rather more insulin than they need for the number of calories they have eaten, the blood sugar may be brought down to too low a level, and the diabetic may pass into a coma by having too little sugar in the blood. Many diabetics in fact carry a little sugar or chocolate about with them to guard against such an eventuality. A story is told of a diabetic in America who, having unwittingly given himself rather too much insulin, began to feel a coma coming on. He felt in his pockets for sugar but found he had none; he staggered into a nearby pharmacist's shop and tried to ask the assistant for sugar. The assistant, however, thought he was drunk and picking him up by the scruff of the neck threw him out into the street. At this he became so angry that his adrenal medulla began to secrete adrenalin into the blood. This caused an immediate rise in the blood sugar and the man 'came to'.

pancreatic ducts of dogs. Banting then read an account of pancreas in which it was stated that the islets of Langerhans were well developed in the pancreas of the foetus before digestive enzymes appeared in the digestive part of the gland. He and Best thereupon set off to the slaughter-houses to collect the pancreases of foetal bullocks. Extracts from such pancreases were found to be active but still the trouble was supply, for foetal bullocks were not very plentiful. Attention was turned, therefore, again to the problem of getting a potent extract from the pancreases of adult bullocks normally killed at the slaughter-houses.

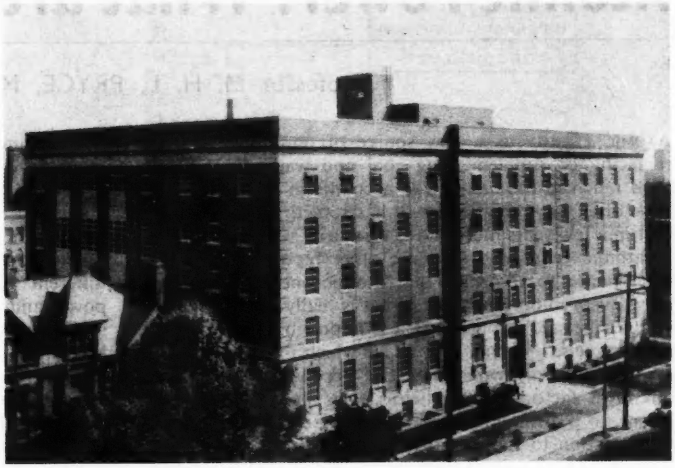
First Trials on Diabetics

They had one success using alcohol and acid as their extracting agents but, much to their chagrin, were unable to repeat it. However, laborious work showed them eventually that there was apparently a critical concentration of alcohol and acid, and they were finally able to reproduce their previous success. Best and Dr. Collip then made valuable contributions towards purifying the extract and making it safe for human injection, and on January 11, 1922, the first patients were treated with extracts of the pancreas (then called 'isletin') at the Toronto General Hospital.

The results were most encouraging, and a new vista of life and health was opened up for the diabetics of the world. Those first patients served as 'guinea pigs', for extracts of various potencies had to be tried on them, dosages worked out, standardisation of extracts to be done. But seeing themselves snatched back from the jaws of certain death these men and women were only too pleased to collaborate in such experiments. That is the story, all too briefly told, of the birth of insulin. Dr. Stevenson tells it vividly with a wealth of intimate detail in the pages of his book.

There were, however, many heart-burnings over the discovery. According to Stevenson, "The original announcement of the discovery came from McLeod, a fact which his juniors did not relish. The announcement was so worded that those who heard it were left with the impression that most of the praise was due to the professor." It is quite probable that McLeod had no conscious intention of diminishing the work of Banting and Best in making the discovery and was seeking merely to obtain some of the fame for the department which he administered. Nevertheless, his action embittered Banting who seems never to have really forgiven him.

It is important to remember in an investigation such as this how much the success of the work, and indeed of many similar outstanding discoveries in medical science, depended upon the chemist. Best was the chemist in the Banting-Best combination, and without Best's help Banting's brightest ideas would never have been put to practical test. Banting, however, had one great virtue, he drew attention constantly to the vital nature of Best's work, and later, when a medical research institute was built for Banting at the University of Toronto, he insisted that it be called the Banting–Best Institute. He was its first director, and although as a director he had certain faults he had many redeeming features. Among these were an almost pathological avoidance of any attempt to gain undue personal credit from the work of any members of his Institute, an approachability which heartened and encouraged the young men working with him and a personal interest in all who worked with him.



The Banting–Best Institute, which is part of the University of Toronto.

Banting's discovery brought him a share in the Nobel Prize (he shared it with Professor J. J. R. McLeod) which involves a considerable monetary reward, and his share he shared again with characteristic generosity with Best. His discovery also brought him a fellowship of the Royal Society and a knighthood. Yet he was not entirely happy. Why? In the first place he became a celebrity at a relatively early age, and in the second place he found himself a celebrity having made an important discovery in a specialised field and having neither clinical training nor any acquaintance with general methods of research. He felt, therefore, at the very height of his fame something of a mis-fit. His ignorance of many fields of research must have handicapped him in his work as director of the Banting–Best Institute, yet he had a gift of getting to the crux of the problem which many of those working under him found most useful.

In 1939 when war appeared to be inevitable, Banting was again anxious to take the field. "I am going to war," he said, "I don't give a damn what as or in what rank, but I am going." Nine days before Canada declared war he accepted the rank of major and a posting as pathologist to a Canadian army hospital in order to get into uniform with the least possible delay. Within a few months he was transferred to work more commensurate with his talents and became a liaison officer between British and Canadian teams engaged on military medical research. He gained a new-found confidence in himself in this war-work and felt he was really doing his bit. It was a sad blow, therefore, to Canada, and the Allies and the world, when Frederick Banting succumbed to a penetrating wound of the lung in the frozen wastes of Newfoundland.

Atomic Power: What are the Prospects?

Professor M. H. L. PRYCE, M.A., Ph.D.

ATOMIC ENERGY as a new source of power, capable of replacing or supplementing coal and water power, has been much in the news. The accounts in the daily press have often been conflicting—it has sometimes been stated that in a few years most of our electricity will be produced in atomic generating stations; other reports have given prominence to the view that atomic energy will never play a very important part. What is really the position?

Let it be said at once that it is impossible at present to give a precise answer. The course which the development of atomic energy will follow still depends on too many unknown factors. Nevertheless, it is possible, to some extent, to put the question against its proper background with relation to some of the more important factors. In this article I propose to consider atomic energy in relation to the supply of raw materials, and how long they may be expected to last, and to the time scale of development. The conclusion to be drawn does not support the optimistic view of atomic power stations in five years, and does not altogether exclude the pessimistic view that it has no important future. It does, however, give hope that in a few decades atomic energy may provide some relief of the fuel shortage.

Let us first consider the nature of the physical processes taking place when atomic (or, to be more precise, nuclear) energy is released, so that we may be clear what kind of applications it may have in the field of power production. The energy, for the most part, appears in the first instance as energy of motion of the fragments of atomic nuclei which have undergone fission. This energy is degraded into heat energy within a very short distance of the site of fission. Some energy is also carried away by gamma-rays and neutrons and is degraded into heat rather farther away (up to a foot). The rate at which heat is produced is controlled by quite simple devices which regulate the fission rate. It is limited by the rate at which heat can be removed to where it can be used, without raising the temperature of the nuclear reactor beyond the limits of safety.

To make use of the energy the heat must be converted into mechanical or electrical energy. As far as can be seen now this will be achieved in essentially the same way as with heat generated from coal, namely by steam- or gas-turbines or similar devices. No practical means has yet been devised, or is likely to be devised, of converting the fission energy directly into electrical or mechanical energy. In this respect nuclear energy plays the same role as does a fuel, such as coal or oil.

Heat can only be converted into useful energy with a reasonable efficiency if it is generated, and delivered to the prime mover, at a high temperature, of the order of several hundred degrees—a fact only too well known to power engineers. In a machine based on nuclear energy the temperature, and so the thermal efficiency, is limited by such factors as the strength of materials, complicated by intense bombardment from neutrons and other radiations, and corrosion, and there is still room for much research into these questions.

A feature peculiar to nuclear energy is that a nuclear machine, or reactor, will not work at all unless it contains a certain minimum quantity of fissile material, large compared with the consumption. It is as though a car would not go unless it had enough petrol in the tank to take it a million miles. This critical size differs greatly in different kinds of reactor. One delivering very little power and needing no cooling devices can be made quite small, but a power-producing reactor needs to be much bigger. Even the smallest pile that has ever been made, for experimental purposes, contains the energy-equivalent in fissile material of many hundred tons of coal.

Another feature not encountered in conventional power plants arises out of the intense radiation accompanying nuclear fission, consisting of beta-rays, gamma-rays and neutrons. The beta-rays are relatively harmless, being stopped by a few millimetres of matter, but the gamma-rays and neutrons have great penetrating power. If they were allowed to emerge where human beings are working they would constitute a grave danger to health, causing the same kinds of disease as are caused by over-exposure to X-rays, and must, therefore, be stopped. This necessitates a radiation shield, several feet thick, of some suitable material such as concrete.

In view of the enormous capital investment in nuclear fuel, and the necessity for cumbrous radiation shields, it is likely that nuclear energy will mainly be used in highly centralised electricity generating plants, the electricity then being distributed over a wide area. The necessity for the strict control of all fissile material required in the schemes that have been proposed at the United Nations

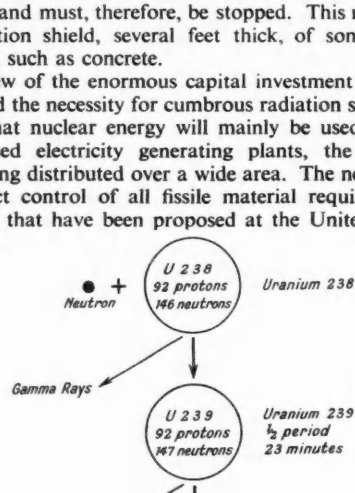


FIG. 1.—Capture of a neutron by a nucleus of U238 leads to synthesis of plutonium, one of the two important artificial fissile materials.

Atomic Energy Commission serves to reinforce this conclusion. The era of atomic cars, trains and aeroplanes seems unlikely to come about. It is possible, however, that nuclear power may be used in big ships.

Three Fissile Substances

There is only one substance found on the earth whose nuclei are capable of sustaining a nuclear chain-reaction, on which the exploitation of nuclear energy relies, namely the isotope 235 of uranium (U235). It is present in uranium to the extent of one part in 140, or 0·7%. There are, however, *artificial* fissile substances, which can be made as products of nuclear reactions induced by the release of nuclear energy. Two, in particular, are of interest as they have a bearing on the problem of the large-scale exploitation of atomic energy. These are the isotope 239 of the new element plutonium (Pu239) and the man-made isotope 233 of uranium (U233). Both have nuclear properties similar to U235, and can in principle be used as the active agents of a nuclear reactor. Plutonium has, in fact, been used already in atomic bombs.

Plutonium is automatically produced in any nuclear reactor using natural uranium (as distinct from uranium in which the 235 isotope has been concentrated by isotope separation). It is formed by the capture of neutrons in the nuclei of the abundant 238 isotope of uranium (U238, abundance 99·3%). The process takes place in three stages (see Fig. 1).

U233 is produced in a similar manner from thorium. To make it, thorium must be

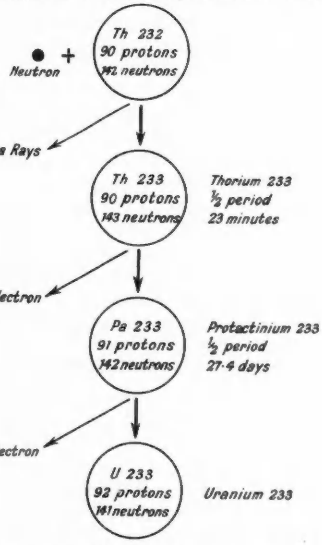


FIG. 2.—Synthesis of U233 from thorium.

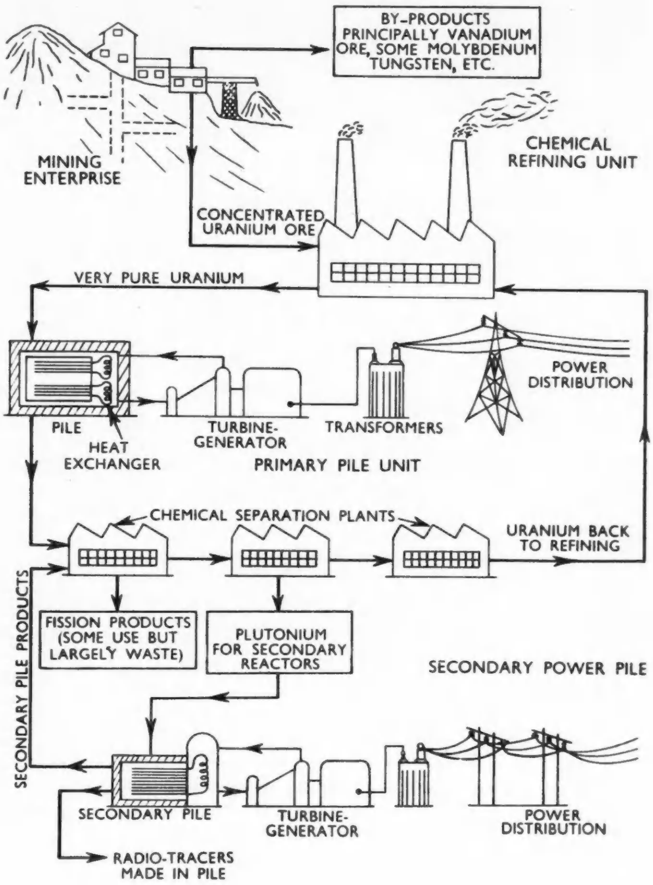


FIG. 3.—This flow sheet indicates the sequence of processes whereby the energy locked in uranium ore could be released and converted into electrical energy for distribution through the electric grid. Two kinds of atomic pile are included in the flow sheet—primary piles running on uranium, and secondary piles, using plutonium synthesised in the primary piles. (*Reproduced from the Proceedings of the Institution of Mechanical Engineers.*)

introduced into a nuclear reactor. Thorium, atomic weight 232 (Th232), is converted by neutron capture into Th233, which after two radioactive transformations becomes U233. (See Fig. 2.)

To understand the bearing of these two fissile substances on the problem let us consider a reactor burning, to start with, ordinary uranium. As the reaction proceeds, U235 is used up, but plutonium appears to replace some of it. Under favourable conditions the reaction will proceed towards a condition in which there is no U235 left; all the fissions then take place in plutonium. Let us suppose this to be happening. For one nucleus of plutonium destroyed by fission some number, x say, of new nuclei of plutonium are produced, on the average, by capture of neutrons in the U238 left behind when the U235 was used up. After a time these x nuclei are destroyed by fission (thereby producing the heat which is the goal of the operation) and each one

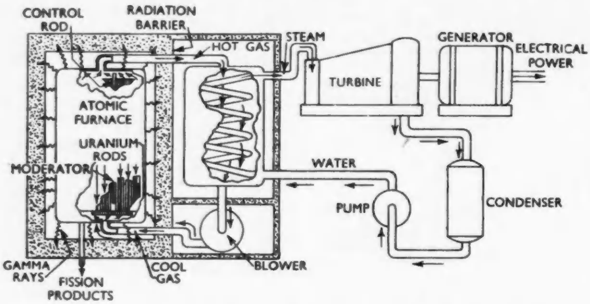


FIG. 4.—This diagram suggests how the heat developed in an atomic pile might be used to drive an electric generator. (*From the Proceedings of the Institution of Mechanical Engineers.*)

produces x new ones, x^2 in all. These in their turn produce x^3 which in their turn produce x^4, and so on. If x is less than one, the amount produced gets less and less, and the total energy generated from plutonium corresponds to the amount of plutonium originally present, multiplied by

$$1 + x + x^2 + x^3 + x^4 + \ldots = \frac{1}{1 - x}.$$

If x is quite near to being equal to 1, this can be quite large, and it is evident that the energy obtained can be appreciably more than the energy directly derived from the U235 initially present.

Breeding

But a most interesting situation arises if x is greater than one. The amount of plutonium in that case increases as the reaction goes on, and can be extracted to be employed in the making of new reactors. This process, still hypothetical, is called 'breeding', for obvious reasons. The increase goes on until all the U238 is used up by conversion into plutonium. A breeding system may, therefore, be regarded as one which effectively burns the abundant isotope of uranium.

Just as plutonium might be bred from uranium, so U233 might be bred from thorium. In this case it would be thorium which would be burnt up in the course of the reaction. The start of a U233 breeding process would be a little different, as thorium would need to be introduced deliberately into the initial stages which depend on the fission of U235, but once the process was under way the principle would be the same.

It is still unknown whether breeding is feasible, in other words, whether x is greater than one. In view of the detailed knowledge acquired in the construction of piles and atomic bombs, it may appear surprising that this is not known. It depends, however, on a very much more delicate balance of neutron production and utilisation than is required for the sustaining of a nuclear chain-reaction, and needs more accurate knowledge of nuclear constants.

Power Demands and Supply of Fissile Materials

We are now in a position to investigate the question of supply and demand—is there enough of the raw material of atomic energy to satisfy the demands for industrial power? The implications of atomic energy are such that we must think of it in global terms, balancing world demand against world supply. As a basis for discussion let us take the thesis that atomic energy is only going to be worth developing on an industrial scale if it is ultimately capable of satisfying an appreciable part of the world's heat and power requirements. Precise figures are difficult to obtain, partly through uncertainty and partly owing to security restrictions, but for our purpose of tracing the broad outlines of the problem they are not necessary. In deciding whether a project is worth considering, an error by a factor of ten either way is in most cases unimportant. The annual world thermal requirements, for all purposes, are roughly 3000 Q, Q being an abbreviation for 1000 million kilowatt-hours. A substantial part of this heat is used in making electricity. It must, of course, be remembered that the conversion from heat to electricity takes place at fairly low efficiency; at 20% thermal efficiency, for each 100 Q of heat only 20 Q of electricity is developed.

Now one ton of fissile material, if completely used up by fission, releases roughly 20 Q of heat. This is equally true for U233, U235 and Pu239, as exactly as we need for the present discussion. It may with interest be compared with the figure for coal—one million tons of coal furnish roughly 7·5 Q. In other words, weight for weight, fissile material yields nearly *three million times* as much heat as coal.

To satisfy the annual thermal requirement of 3000 Q we need $3000/20 = 150$ tons of fissile material per annum.

In terms of raw materials (uranium, thorium) this demand takes very different forms according as breeding is or is not a practical possibility. Let us first consider the pessimistic hypothesis that breeding is not possible. Then the fissile material available is U235, together with plutonium formed as a by-product of its fission. The secondary plutonium might multiply the effective amount of fissile material by a factor of five without straining the hypothesis too much. The raw material in this case is uranium, containing 0·7% of U235, equivalent, with this estimate of the effect of secondary plutonium, to $5 \times 0{\cdot}7\% = 3{\cdot}5\%$ of fissile material for the purpose of heat production. The uranium requirements are, therefore, $150 \times 100/3{\cdot}5 =$ (roughly) 4000 tons a year.

Let us now turn to the more optimistic hypothesis that breeding is possible. The raw materials are now either uranium or thorium, according as we use plutonium or U233 as the fissile material. In the breeding process the raw material gets converted into fissile material, and the consumption must be considered essentially as consumption of raw material. This means an annual consumption of 150 tons of uranium or thorium as the case may be.

These requirements must be related to the available supplies. Uranium is not a really rare material. It is, for instance, more plentiful than gold. But it occurs, for the most part, in very low concentrations in rocks such as granite, from which it is not economical, at least with any method known at present, to extract it. Rich ores, such as those of the Belgian Congo and Great Bear Lake are relatively rare, and only a limited total quantity of uranium is available from them. It is difficult to estimate the world's stock of uranium from workable ores, as it still remains

FIG. 5.—This model, part of the atomic exhibition now on show at the American Museum of Natural History in New York, makes the idea of industrial atomic power a little less remote to the average layman.

a military secret—but a rough guess, not likely to be out by more than a factor of ten, can be attempted. For the present discussion let us assume that the world's supply of uranium will continue at the pre-war rate of 1000 tons a year available from good ores for, say, ten years—making 10,000 tons in all for that period.

Thorium is more abundant than uranium and already before the war was mined for its industrial applications to the extent of from 500 to 1000 tons annually, and there seems no reason to believe that the world's stock will not last for centuries at this rate.

With these figures we see that, on the assumption that breeding is *not* possible, the 10,000 tons of uranium suggested would be sufficient for only two and a half years' work when used up at the rate demanded by total replacement of existing sources of power by atomic energy. The extreme roughness of this figure must be stressed. It might quite well be as long as 25 years, or as short as three months. One broad conclusion can be drawn. If breeding is impossible, the future of atomic energy as a long-term substitute for coal depends on the economical extraction of uranium from low-grade ores, the rich ores being able to satisfy the demand for only a short period.

On the assumption that breeding is feasible, however, the situation is rather different. With uranium, consumed at the rate of 150 tons annually, the assumed output of high-grade ores is enough to last 10,000/150 or roughly 70 years. Making allowance for our uncertainties, let us say between 7 and 700 years. Clearly, more precise figures would be desirable, but even in their absence the situation looks more hopeful. The long-term solution may still depend on the extraction of uranium from low-grade ores, but the time available for development of the extraction techniques is more reasonable.

With thorium, assuming breeding of U233 is possible, the annual demand of 150 tons is quite small compared with the pre-war annual output of thorium, and the exhaustion of supplies seems remote. If breeding of U233 is feasible, therefore, there is every reason to believe that atomic energy can play a very important part in power production.

Time scale of Industrial Development

Let us now inquire into the time scale of the development of atomic energy for industrial purposes. Without breeding, this is mainly determined by the time required to develop, and put into large-scale operation, methods of extraction of uranium from poor ores—I would prefer not to commit myself to a figure for this, though I would guess the time to be measured in decades. The present piles, which use natural uranium, contain a capital investment of uranium equivalent to the consumption of decades; if the future reactors are going to be similar in this respect, the initial amounts of uranium required are going to be much greater than the annual consumption or even than the stocks from high-grade ores. This consideration will further retard the development.

The really interesting case is U233 breeding from thorium. The development can be considered in two main stages. The first stage is the burning of U235 (the only naturally occurring fissile material) and the synthesis

of U233. The second is the breeding proper, atomic power being developed in reactors containing U233 and thorium.

In the first, or conversion stage, the reactors contain natural uranium, which, because of the high degree of neutron loss in U238, present little flexibility of design and are limited to relatively low rates of heat extraction, and therefore of conversion. Allowing time for research into the problems involved, and for a major constructional programme, a figure of ten years does not seem unreasonable for the conversion stage.

The product of the conversion is U233. Assuming all the world supplies of uranium were accumulated over our hypothetical ten-year period and stock of uranium invested in this programme, we start with $10{,}000 \times 0{\cdot}7\% = 70$ tons of U235, which is converted, at probably a good deal less than par, into U233. For the sake of argument, let us suppose that the yield is 50 tons of U233.

The next question is how quickly the U233 multiplies. This depends on two main factors:

(*a*) The average number of fissile nuclei, in excess of one, which are produced when a nucleus is destroyed by fission. In other words what we have called $x - 1$.

(*b*) The average time that elapses before a nucleus in the reactor undergoes fission.

As we have seen, x is so uncertain that it may not be even greater than one, but, on the assumption that it is, we can estimate the order of magnitude of $x - 1$—it is probably quite small. For the present discussion let us assume that it is 0·1, i.e. $x = 1{\cdot}1$; for each 10 fissile nuclei that disappear, 11 new ones are born. Or, in the language of investment, the interest rate is 10% per life-cycle.

The average life-time of a fissile nucleus in the present types of pile is not a published figure, but within the accuracy of a factor of ten either way it may be estimated from published material to be between 10 and 1000 years. It is clear that unless a much shorter life-cycle can be achieved, the building-up period will be very long. The problem is essentially one of heat-transfer—the quicker heat can be removed, the quicker can be the fission rate, and the shorter the life-cycle. In fact, the U233 reactors will not be subject to such limitations on materials and mode of construction as piles using natural uranium, and it is reasonable to expect that a great improvement can be made over present-day piles. To fix our thoughts, let us assume that a life-cycle of one year can be achieved, with our usual proviso about the factor of ten. Actually, it cannot be very much shorter, for besides the time that the U233 takes in undergoing fission we must also consider time spent in chemical extraction and purification, which is probably necessary between cycles; because of the fact that U233 is only formed after two radioactive transformations, which take time, and because of the high initial radiation level from the radioactive fission products, the chemical processing time is probably of the order of months.

Combining these figures ($x = 1{\cdot}1$, life-time = 1 year), we arrive at an interest rate of 10% per annum.

We have assumed that we shall be starting the breeding stage with 50 tons of U233. After one year the amount of U233 will be $50 \times 1{\cdot}1 = 55$ tons. After two years, $55 \times 1{\cdot}1 = 60{\cdot}5$ tons; and so on. The ultimate requirement is for a *consumption* of 150 tons per annum. We can estimate what this means in terms of capital stocks from the assumption that the life-cycle of U233 is one year. This gives us a capital requirement, ignoring the needs for reserves and other possible diversions, of 150 tons. Let us assume another 150 tons for reserves, etc. This makes the eventual requirement 300 tons. At 10% per annum, this takes 19 years ($50 \times (1{\cdot}1)^{19} = 306$). Let us say 20 years for the sake of a round number.

On the basis of these particular figures we conclude that it would take thirty years (10 + 20) to develop atomic energy, operating on a breeding principle, to the stage where it could effectively replace other sources of power. The extreme roughness of this figure cannot be over-emphasised. But what is important is the *order of magnitude*. Atomic energy cannot be developed on an industrial scale in five years, nor is the development likely to need several centuries (unless indeed all the pessimistic hypotheses are the correct ones, in which case it will play no useful part in power development).

The foregoing estimates have been made on the assumption that the aim is almost total replacement of existing sources of power by atomic energy, but the conclusions are not very different if the aim is merely to alleviate the difficulties of the coalmines in this country. It is the initial stages of the development which take time. Nor does treating the problem on a national, instead of a global, basis make much difference: present British power needs are about 10% of the world total; the British allocation of raw materials is unlikely to be much different from 10% of available supplies.

Cost of Atomic Power

In view of the great technical uncertainties concerning the development of atomic energy, it is premature to forecast the cost of power produced from atomic energy, but it may be interesting to mention that an official American report on the probable cost of electricity from an atomic generating plant, using techniques rather similar to those in use in existing atomic piles, estimates it to be comparable with the cost of electricity generated from coal.

Quite apart from the still unknown snags to be met with in the technical development, it will be seen that there are two major uncertainties concerning the future of atomic energy—the possibility or otherwise of breeding and, if it is impossible, the economic extraction of uranium from low-grade ores. If no satisfactory answer is found it may well be doubted whether atomic energy has any useful large-scale future. If, on the contrary, one or other uncertainty is satisfactorily resolved, a few decades from now may well see the large-scale use of atomically generated power, and the raw materials ought to last sufficiently long to allow human ingenuity to find new sources of power before they run out.

READING LIST

Recent articles containing useful information on this subject include the following:

"Economic Aspects of Atomic Power", by J. Marshak, *Bulletin of the Atomic Scientists* (Chicago), Vol. 2, Nos. 5 and 6, 1946.

"Metallurgical Problems involved in the Generation of Useful Power from Atomic Energy", by Sir W. Akers, *Nature*, Vol. 159, p. 534, 1947.

"The Possibilities of Nuclear Energy for Heat and Power Production", by J. D. Cockcroft, *Proceedings of the Institution of Mechanical Engineers*, Vol. 156, p. 206, September, 1947.

See also "Atomic Piles" by L. Kowarski, *Discovery*, 1946, Vol. 7, pp. 299–301.

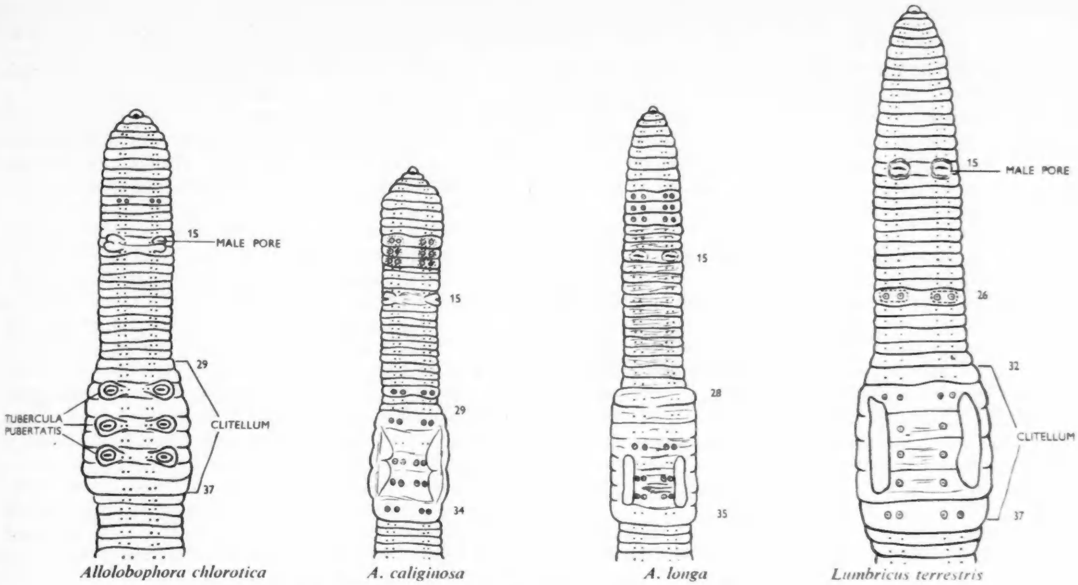


FIG. 1.—These drawings of the front end of four common earthworms show the principal external characters upon which identification of the species may be made. *Allolobophora chlorotica* is $1\frac{1}{2}$ to 2 in. long; *A. caliginosa*, 2 to 4 ins.; *A. longa*, 6 to 9 ins.; *Lumbricus terrestris*, 9 to 12 ins. The male pores are to be found on the fifteenth segment in all species. Certain setae (bristles) are elongated and situated on small protruberances on various segments according to the species, e.g. on segment twenty-six in *L. terrestris*. The segments forming the 'saddle' (clitellum) vary in number; the first and last are numbered in each case. The clitellum bears on the underside slight protruberances, called the tubercula pubertatis, often of characteristic shape.

Earthworms and the Soil

A. C. EVANS, Ph.D.

DARWIN in his book, *The Formation of Vegetable Mould Through the Action of Worms*, published in 1881 stated "it may be doubted whether there are many other animals, which have played so important a part in the history of the world as have these lowly organised creatures."

Several scientific investigations have been carried out between 1881 and the present time to determine the effect of earthworms on soil fertility, and all the investigators with one exception concluded that earthworm activity brought about increased yields of the test crop.

Recently there has been an outburst of interest in earthworms, particularly in America. Earthworms are eulogised as 'the farmer's never weary workers', 'the ploughs of God' and 'the master builders of the topsoil'. A system of earthworm farming has been developed which, it is claimed, 'transformed an infertile desert hillside into a home-site of almost tropical luxuriance'. Earthworm cocoons, which contain the eggs, have become an article of commerce, and special strains—'the coolie worm', 'the commando worm' and 'the soilution worm'—have been developed. This latter is claimed by its originator, Dr. Oliver of Texas and California, to be a cross between the orchard worm (*Lumbricus terrestris* L.) and the English brandling (*Eisenia foetida* Sav.). Fertilisers and sprays are frowned upon as killing hundreds and thousands of earthworms per acre, so causing the loss of valuable collaborators in the maintenance of fertile soil. Such claims are not based on a sound foundation of facts.

When the Rothamsted investigations began just over three years ago I was astonished at the small amount of knowledge available on these common creatures; not even the bare outlines of the life-cycle of even one species was known. Without such knowledge suitable experiments cannot be carried out nor field observations interpreted correctly so as to appreciate their importance.

Ten species studied

The work carried out during the past three years has proceeded along three main lines:

(*a*) laboratory studies on the details of the life-cycles of ten species commonly found in agricultural land and in accumulations of organic matter such as compost heaps, peat, etc.;

(*b*) field studies on the factors determining the numbers of worms in fields of varying agricultural treatments and soil types, and the effects of these populations on the soil;

(*c*) pot experiments on the effects of earthworms on plant growth.

The laboratory and field studies have shown that earthworms cannot be regarded as a group of animals with very

similar habits. The various species* differ considerably in a number of ways and these differences are of importance in considering the effects of earthworms on the soil. For instance, it has been discovered that on the Rothamsted Farm only two species, *Allolobophora longa* Ude (see Fig. 1) and *A. nocturna* Evans, produce wormcasts, other species ejecting the soil which they consume into air spaces below the soil surface.

These two species also differ from the other species present in that, during May-June, they retreat to a depth of 6 to 12 in., roll themselves into a tight ball in a roughly spherical chamber and remain in a state of rest until September to October. This phenomenon occurs even though soil conditions are suitable for activity. Other species of the genus *Allolobophora* only go into such a state of rest (diapause) when the soil is too dry or too cold for activity. Members of the genus *Lumbricus* have not been observed to behave in this manner; when the soil is cold or dry they move down into the warmer, moister subsoil.

Only three species have been observed to feed on the soil surface at night, *A. longa*, *A. nocturna* and *Lumbricus terrestris* L., and only the latter has been seen mating on the surface. It would appear that most species mate underground or inside compost heaps, etc.

Earthworm populations

The histories of the various fields at Rothamsted are known in detail, and advantage was taken of this in a study of the earthworm populations of fields which have received different agricultural treatments. It was found that grass fields over five years old carried populations varying between 200,000 and 653,000 per acre; arable fields had much lower populations, of about 100,000; and grass fields down for 1 to 2 years after arable were intermediate. Considerable differences in the proportions of the different species present on the various fields were found. *A. nocturna* and *A. longa*, the two worm-casting species, form 50 to 60% of the population on well-established permanent pastures but only 1 to 30% on leys and arable fields. On old arable fields, small earthworms such as *A. chlorotica* Sav. and *Eisenia rosea* Sav. often form the bulk of the population; larger species do not seem to find a suitable environment in these fields. In leys *A. caliginosa* Sav. and the so-called common earthworm *L. terrestris* are the common species.

The weight of earthworms present in a field can often be very high. On Parklands, a field at Rothamsted, which has been under grass for over 300 years, there was a weight of about 1000 lb. per acre, and on a field in a Yorkshire dale it was probably nearer 1500 lb. Arable fields carry a much lighter population—50 to 120 lb. per acre—and leys vary considerably according to age—170 to 800 lb. per acre. The great difference in the weight of earthworms on permanent pastures and arable fields is due largely to differences in the amount of food. Much more food in the form of dead leaves, roots and dung is available on grass than on arable.

The type of soil is also a factor in determining earthworm populations. My colleague, Dr. W. J. McL. Guild, carried out a survey of the soil types in the Carse of Stirling, Scotland. He found the highest populations on light loams and the lowest on clay and gravelly sand. There were also considerable differences in the proportions of the various species present; on the clay soils *L. terrestris* and *L. rubellus* Sav. formed only 13% of the population but 40% on the gravelly sand. *A. longa* formed 31% of the population on clay and medium loam and only 17% on gravelly sand. *A. nocturna*, the most common earthworm on permanent pasture at Rothamsted, was not found in the Carse of Stirling, being replaced by *A. longa*.

Wormcasts by the Ton

The production of wormcasts is one of the signs of earthworm activity. Darwin estimated that earthworms throw up an amount of soil equivalent to 8 to 16 tons per acre per annum on some of his fields. Continental investigators have produced further estimates varying from 2 up to 36 tons per acre per annum on various soil types. The record estimate is 107 tons per acre per annum in the valley of the White Nile, Sudan. All of the estimates obtained are based on one or two plots and so may not be very accurate. Early in the investigations at Rothamsted it was decided that a study of wormcasting should be carried out to obtain accurate estimates of the amount of soil thrown up in the form of wormcasts and also as an indication of the effect of soil conditions on earthworm activity. Twelve plots were marked out in a permanent pasture, and the casts were collected every four days, for two years. The average cast production was 11·5 and 11·0 tons per acre for the two years. It was found that soil conditions played a very important rôle in determining wormcast production. This was high in October-November and February-March when the soil was moist and warm, it was low between November and February, because the soil was cold, and between April and October, because the soil was too dry for maximum activity.

Because of the great variation in numbers and kinds of earthworms found on the Rothamsted fields it was thought that interesting results would be obtained on these fields. Eight fields were chosen, and the wormcasts produced on a number of

* The identification of the British species is described in *The Lumbricidae*, by the late L. Cernosvitov and A. C. Evans, Synopses of the British Fauna, the Linnean Society of London.

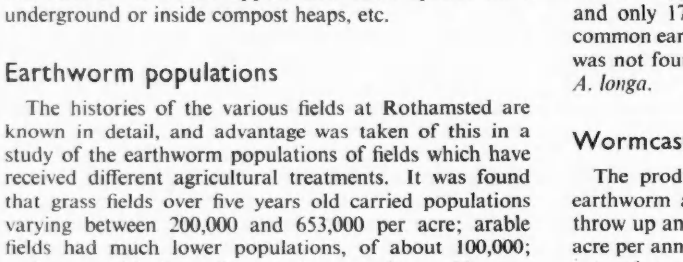


FIG. 2.—The distribution of stones and coarse sand in the soil to a depth of eight inches. (See text.)

plots over a fortnight were dried and weighed. These plots were treated with a chemical which brought the earthworms to the surface, so making it possible to obtain an estimate of the numbers and weights of the different species on the plots. As a result of the two years' intensive study it was possible to convert the wormcast yields for the eight fields into tons per acre and annum. The results are shown in Fig. 3. On Parklands, the production was equivalent to 25 tons per acre per annum, on two other old-established grass fields it was 11 tons, on the arable field, Delharding, 2·8 tons and on the remaining fields, leys of various ages up to seven years, it varied between 1 and 6 tons. The figure also shows the total numbers and the numbers of wormcasting species per acre on the various fields. It is clear that the wormcast production depends only on a portion of the total population; the field called Pastures has the second highest population but has a very low wormcast production. From the data available it is possible to estimate the amount of soil consumed but excreted below the surface by the non-wormcasting species. This figure added to the wormcast production gives the total amount of soil swallowed per acre per annum by the total worm population. It amounts to the considerable figure of 37 tons for Parkland, and only New Zealand (1-year ley) and Delharding (arable) have low totals. (For details of the agricultural history of the eight fields, see footnote on this page.

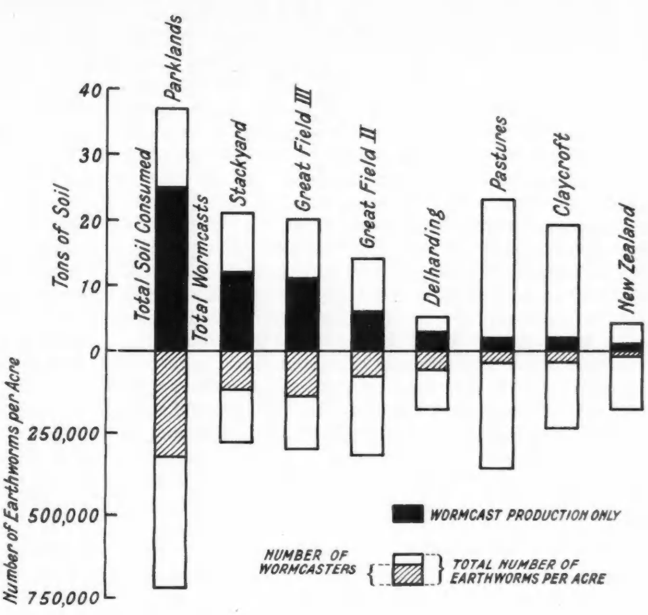


FIG. 3.—For eight fields at Rothamsted the production of wormcasts per acre is shown (solid black column) superimposed on the total amount of soil consumed by earthworms per acre. The bottom half of the figure shows the proportion of earthworms in each field which account for the wormcasts. Brief details of the agricultural treatment that each of the eight fields have received are to be found in the footnote at the bottom of this page.

Data on the weight of soil per acre for successive 2-in. depths was obtained for some of the fields. From these it was calculated that the wormcasts produced on Parklands, Great Field and Pastures were equivalent to a layer of soil respectively 0·24, 0·10 and 0·02 in. in thickness and that it would take 11, 20 and 21 years for the top 4 in. of soil to pass through the digestive systems of the earthworms present.

Artificial fertilisers don't kill worms

The use of artificial fertilisers, particularly sulphate of ammonia, on our farmlands is strongly deprecated by adherents of the 'modern humus school'. Evidence for this view is sparse, consisting of superficial observations and special cases, such as golf greens and tennis courts, on which sulphate of ammonia is deliberately used to get rid of earthworms.

No evidence has been found at Rothamsted to justify these views. The grass fields receive a top dressing of approximately 2 cwt. of sulphate of ammonia per acre per annum and other fertilisers as required, and most of them carry high earthworm populations varying in weight from 6 to 10 cwt. per acre. The number of wormcasts on the Park Grass plots were studied by Dr. H. L. Richardson in 1934. Results from the limed half of some of the plots are given in the table below.

The highest yields of hay are given by the plots receiving complete fertilisers but with the lowest wormcast production. The maximum production of casts occurs on the organic plots; this might be expected since 14 tons of

	Number of casts (thousands per acre)	*Hay cwt. per acre*
14 tons farm-yard manure every other year	337	35
Minerals	252	33
Sulphate of ammonia + minerals	127	49
Nitrate of soda + minerals	161	51
Unmanured	276	11

The agricultural characters of the eight fields studied by Dr. Evans from the point of view of earthworm population are as follows:

Parklands, permanent grass, several centuries old.

Stackyard, pasture about eighteen years old; broken up in 1946.

Great Field III, old grass, established about 1870.

Great Field II, as Great Field III but ploughed for oats 1943 and 1944, then back to new grass in 1944 in which it still remains.

Delharding, old grass, about 1870; ploughed up in 1942 and still under crop.

Pastures, long ley established on old arable land in 1938 and still in existence.

Claycroft, new grass established in 1943 on former woodland.

New Zealand, pasture about eighteen years old, broken up in 1943 and returned to grass 1945 after three arable crops.

farm-yard manure every other year represents a considerable addition to the food supply of the earthworms, but this increased earthworm activity does not result in the maximum yield. The plot treated with minerals and sulphate of ammonia *without lime* produced no worm-casts and has developed a considerable surface mat. No trace of this mat is to be found on the corresponding limed plot. The earthworm population of this plot is clearly sufficient to prevent the formation of a mat and the consequent deterioration of the grass. Similarly on Broadbalk (wheat for over 100 years), the highest earthworm population occurs in the dunged plot, but those plots which have received sulphate of ammonia annually for over a century have the same population as comparable plots without sulphate of ammonia. The treatment of acid pastures with fertilisers brings about distinct improvements in the worm population. Untreated pastures contained 52,000 per acre, pasture treated with lime and compound fertiliser or super-phosphate and sulphate of ammonia contained 188,000 and 219,000 respectively. The increase chiefly consisted of typical pastureland earthworms.

Effect on soil structure

Much of the food of earthworms lies on the surface of the soil, in the form of dead leaves and animal droppings. This is buried in two ways, by the formation of wormcasts on top of it and by the worms pulling it down into the soil where they consume it. In this way the formation of a surface mat* which would kill out the finer grasses is prevented. The accumulation of wormcasts on the surface causes a redistribution of coarse material in the profile, the top 4 to 8 in. of soil becoming free of stones. Fig. 2 shows the depth distribution of stones for two fields, Great Field III and Pastures, the one a 70-year-old pasture, the other a seven-year-old ley following many years' arable.

The distribution of stones in the profile of Pastures is approximately uniform as is that of coarse sand (sand particles with diameters ranging from 0·2 to 2·0 mm.). The action of earthworms during the seven-year ley has not brought about any measurable change. However, the casting activity of the earthworms on Great Field III during 70 years has brought about a considerable reduction in the weight of stones in the top 4 in. and an increase at 5–8 in. A gradient of coarse sand has also been established, the proportion in the soil increasing significantly with depth.

The pore space (a measure of the space occupied by air and water) is also considerably affected by earthworm activity. The top 4 in. of two arable fields in wheat stubble had a pore space of 45%, and for two pasture fields, Parklands and Great Field III, it was 59% and 57%; the activities of the wormcasting species in these two fields were responsible for the considerable increase. In Pastures field (seven-year ley) the pore space was 40%; significantly lower than that of the arable fields. Thus it would appear that the combined action of rain and treading by stock has brought about a consolidation of the soil during the last seven years, and earthworm activity has not been able to compensate completely for this.

There still remains a great deal to be learned about the activities of earthworms and their rôle in agriculture. From what has been learned about them during the three years' work at Rothamsted, it would appear that their rôle is unimportant in arable cultivation; our machines open up the soil and bury organic residues which are then decomposed by bacteria. On permanent pastures, broad-leaved forests, and waste lands they probably perform many valuable functions, burying and decomposing organic matter and keeping the soil aerated and well drained.

* The term 'mat' is applied to the accumulation of partially decayed organic matter (dead leaves and animal droppings) on the surface of the soil; an extreme form is peat.

WHEN A SCIENTIST BLINKS

Most of us are completely blacked-out for about 10% of the time we use our eyes; we blink once in 2·8 seconds, and during the blink our eyes are completely closed for about 0·3 seconds. These figures refer to the most common type of blinker. In other extreme cases the proportion of black-out may be as much as 40%. Furthermore, the blink is preceded by a movement of the eye-ball which adds about another quarter of a second of indistinct or uncertain vision, so that in the common case vision is unreliable for about 20% of the total time, and in extreme cases for about 70%.

Blinking can obviously make a difference to one's success in a sport like tennis. This interruption of the vision may also be important in an everyday occupation such as driving a motor car; it would be surprising if the bad blinker were not more accident-prone than the average person.

Dr. Robert W. Lawson, writing in *Nature* (1948, Vol. 161, pp. 154–7), has pointed out that these facts are important in research work as they have a bearing on the collection of certain physical measurements. This will occur when the experimenter has to observe events whose duration is short compared with the black-out period. An example occurs in measuring one of the most important constants in radioactivity, namely Z, the number of α particles emitted each second by a gram of radium. This constant has been measured in many different ways, and the values obtained have differed considerably—ranging from $3{\cdot}40 \times 10^{10}$ to $3{\cdot}72 \times 10^{10}$ (the latter is the accepted value). The lowest value was obtained by Geiger and Werner using the method of counting the scintillations produced when an α particle strikes a zinc-sulphide screen. The scintillation lasts a mere ten-thousandth of a second, so that the black-out effect can upset the measurements. Unfortunately, no details are available concerning Geiger and Werner's blinking behaviour, but an allowance of the common 10% black-out world bring their result into line with the standard.

Scientists have long known that, except when using automatic recording methods, they have to take account in their experiments of the idiosyncrasies of their own nervous systems. They make allowance for this by what they call their 'personal equation'. As physiological knowledge increases the general tendency is to find more and more factors which must be allowed for. Blinking black-out is an important addition to the list.

Evolution of British Natural History

R. P. HILL, B.Sc., A.R.C.S., D.I.C.

NATURAL history began when early man first taught his children how to distinguish between edible and poisonous berries. The fund of knowledge grew until there was enough of it to enable man to interfere with the course of nature—to plant crops, to domesticate and breed animals. This made possible the first truly civilised communities, societies wherein some men at least had the leisure in which to think and to try to satisfy their curiosity. These ancient civilisations came and went. Some, like that of Crete, must have reached considerable heights—Daedalus was a Cretan—but the few written records we have of their achievements are undecipherable.

The earliest civilisation of which we have anything like a complete record is that of Greece or, more particularly, of Athens. Because of its novel democratic structure its citizens were much concerned with argument and the arts of eloquence. But, as Wells says, "one cannot reason without matter, and knowledge followed in the wake of speech". Socrates declared war on bad argument; his pupil Plato made a searching examination of political institutions; and Plato's pupil Aristotle, realising the necessity for exact knowledge, sent out explorers to collect facts. At this point natural history became a science.

The lamp that Aristotle lit never quite went out. It died to a glimmer as Greece wasted away in the Peloponnesian Wars; it waxed to a blaze in Alexandria under the first two Ptolemies; the Arabs found it, rekindled it, and carried it wherever they went; in Moorish Spain it flickered fitfully until the thirteenth century; and in the laboratories of the alchemists it remained secretly alight until the Renaissance. But for most of Europe the light went out towards the end of the first century B.C. and stayed out for fifteen hundred years.

The story of natural history in England begins when these Dark Ages were at their darkest: it is a story of men struggling, often blindly, towards the light. That they took so long to reach it is evidence of the strength of the forces against which, often unwittingly, they strove. These forces had their origin in the religion of the time, and the manner of their origin can be understood only after a study of the history of religious movements. The gods of Athens and early Rome were social gods; their worship was a polite and meaningless ritual, and their priests were subservient to the state. But in Egypt there had developed the religion of Serapis-Isis-Horus whose gods, particularly Isis, were personal gods and whose central theme was personal immortality. The worship of Isis became popular among the upper strata of Roman society as that of Mithras, another immortality religion, spread among the slaves. The growing demand at all levels for such a religion was met by Christianity which, within three hundred years, had become the official religion of the Roman Empire.

It would be too great a digression to discuss at length the development of doctrinal Christianity, the emasculation of the original revolutionary teaching, the Church's bid for absolute political power; yet these were the things that shaped the thought of the times. Tolstoy has defined a man's religion as his conception of his relation to the universe and to the powers behind the universe. Tolstoy meant that a man's conception should be his own, but the early Church would allow him no such freedom. It set out to define once and for all the relationship existing between man, God and the universe, and to impose that definition upon all mankind. Thus over the years there was built up a dogma of vast proportions which was claimed to contain all truths and the ultimate truth, to provide an answer to all questions and a solution to all problems. To attempt further investigation in any field implied a lack of faith in the validity of the dogma and invited the severest punishment: scholarship was stringently confined to the interpretation and amplification of existing dogmata. Had these dogmata borne any relation to reality progress of a kind might still have been possible. Unfortunately the entire fabric was unreal—so unreal that in the end it had to be bolstered up by the distortion and suppression of evidence and by such devices as the Holy Inquisition.

The effect of this atmosphere on natural history was profound. The Greeks and early Romans knew of one world—this world—and their interest was focused upon it. The Christians knew of two. St. Augustine in *De Civitate Dei* shifted the emphasis of the older teaching to prove the utter worthlessness of the secular world, and a politically convenient distortion of this doctrine has been propounded ever since. As a result of it facts, which spring from the study of things of this world, were held to have no intrinsic value. They could be useful in reinforcing a point of doctrine or in constructing a moral tale, but it was perfectly legitimate to trim or distort them if they did not quite fit or to place them alongside the most outrageous inventions. Aristotle was often wrong. He accepted and noted everything his collectors brought him without verification—and it seems that he employed a number of men whose imagination was less clouded than their eyesight. Yet Aristotle would never have agreed that the publication of statements demonstrably false could serve any useful purpose. He would have been happier in the twentieth century than at any time in the Middle Ages.

To a twelfth-century scholar interested in natural history Aristotle, Galen, Dioscorides and even Pliny were legendary sages of whom nothing was known at first hand. His authorities were St. Basil, author of the *Hexaemeron*—a series of Lenten sermons on the works of creation delivered in 370; St. Ambrose, who produced a similar *Hexaemeron* nineteen years later; Isidore, Archbishop of Seville, whose *Origines*, although written at the beginning of the seventh century and stuffed with etymological nonsense, remained the most authoritative text-book until the Renaissance; and the *Physiologus*, a book of unknown origin which was amplified and translated into most European languages to become the 'Bestiary'. To this list might be added Caius Julius Solinus, a Roman of the third century A.D., thought at one time to be a contemporary of Julius Caesar. His *Polyhistor* was a compilation of

works, mainly those of Pliny the Elder. Of these the 'Bestiary' was certainly the most widely distributed. In its pages the lion and the unicorn, the eagle and the phoenix rub shoulders on equal terms while the habits ascribed to the real beasts are no less improbable than those of the fabulous. It has been said that not a single statement in it can be accepted as fact—which is not surprising since its unknown authors were not in the least concerned with facts. It is a typical piece of mediaevalism.

In Britain, the credit for making the first improvement on the 'Bestiary' must go to Alexander Neckam, who was born at St. Albans in 1157 on the same night as the prince who became Richard Cœur-de-Lion. He is said in fact to have been the prince's foster-brother. Educated at the Abbey where he was born, he later studied law, medicine and theology at the University of Paris. He returned to England in 1186, joined the Augustinians of Cirencester about 1203, became their abbot in 1213 and died in 1217. His two major works are the *De Naturis Rerum* and the *De Laudibus Divinae Sapientiae*, a version of the former in Latin verse. Neckam bases his classification on the mediaeval cosmology. The chamaeleon, for instance, was believed at that time to live on air. It is, therefore, in a section of its own, taking precedence over the birds and flying insects which merely live in the air. For the same reason fish, which live in water, are dealt with before animals which live on or in the earth. Many of his creatures, like the Phoenix, the Amphisbaena, the Basilisk and the Dragon, are entirely legendary; others are real, although he perpetuates the legend that the osprey ('Aurifrisius') has one foot clawed and the other webbed. Yet there are occasional flashes of genuine observation, as when describing the parrot's strong beak and its fondness for its own reflection in a mirror. In the *De Laudibus* the old and persistent legend of 'crocodile tears' is recorded together with another curious notion concerning the same animal, that when eating the crocodile moves the upper jaw and not the lower. Like Isidore, Neckam is obsessed with the importance of derivations. He puts forward, for example, a suggestion that the word *cadaver* is derived from the first syllables of the phrase *caro data vermibus*—a curious foreshadowing of the modern trend that has given us words like *Gestapo*.

Of the three great English Franciscans who followed Neckam—Grosseteste, Bartholomew and Roger Bacon—it was Bartholomew, the least of the three, whose contribution to natural history became most widely known. Grosseteste anticipated the Renaissance in undertaking between 1224 and 1235 a research into original Greek and Hebrew writings and even went so far as to advocate the application of experimental methods to the natural sciences. Yet he contrived to avoid a charge of heterodoxy and rose to be Bishop of Lincoln. His earlier work was taken up by Roger Bacon, a genius so far in advance of his time that his influence on its thought was slight. Bacon's independent and inquiring spirit soon got him into trouble with the authorities of his Order and ultimately with the Pope. His extant works clearly demonstrate his refusal to take things as he found them; he deplores the inaccessibility of ancient original manuscripts, he urges the importance of exact descriptions, of direct experiment and of the testing of hypotheses. In this last he anticipates his namesake Francis Bacon whose advocacy of the inductive method at the beginning of the seventeenth century laid the foundations of modern philosophy.

There is some doubt as to the precise date of Bartholomew's work *De Proprietatibus Rerum*. The earliest known manuscript is dated 1296, and it seems probable that the bulk of *De Proprietatibus* was written in the middle of the thirteenth century.

Legends overshadowed accurate observation

Bartholomew shows no signs of the originality that marked Grosseteste and Bacon apart from their contemporaries; unlike Albert he is interested neither in experiment nor verification. The book is a vast encyclopaedia of current tradition, much of it debased from older authorities, relieved by rare instances of genuine observation. Of the legends to which Bartholomew gives credence, two are worth noting. These are that vultures hunt by smell and that 'barnacle-geese' arise from 'goose-barnacles'. Both these legends persisted for many centuries after Bartholomew, yet they had been exploded a little before his time by that extraordinary man the Emperor Frederick II (*De Arte Venandi cum Avibus*).

In many respects the debasement and distortion of the older authorities reached a climax in Bartholomew. Professor Raven* gives a number of interesting examples of which the best is the story of the crocodile-bird. Herodotus (*Histories*) tells of a bird called the trochilus (a plover) which is allowed by the crocodile to enter its mouth to pick off leeches—a story which may well contain an element of truth. Aristotle (*Historia Animalium*) embellishes the story a little but leaves its essentials untouched. Pliny (*Historia Naturalis*), in addition to mistaking the trochilus for the wren, gives the story a new twist by stating that the crocodile is made sleepy by the bird's attentions upon which the ichneumon (believed by Pliny to be the enemy of the crocodile) "darts into his throat and gnaws out his belly". Solinus (*Polyhistor*) repeats Pliny but lays more emphasis on the pleasure derived by the crocodile from the bird's scratching. Isidore does not mention the story. Neckam calls the bird 'strofilos' and confuses it with Pliny's ichneumon so that the bird appears to perform the tasks of both. Bartholomew calls the beast a 'Cockadrylle' and the bird 'Cuschillos', and tells a well-rounded tale in which the beast is lulled asleep by the bird's gentle ministrations, upon which "this byrd Cuschillos . . . descendeth into his wombe, and forthwith stycketh hym as it were with a darte and byteth hym full grevously and fulle sore".

The beginning of the Renaissance is traditionally linked with the fall of Constantinople in 1453. The new learning spread from Italy to France, the Rhineland, the Low Countries, and only then to England. Yet there were signs that England was ready to receive it. These signs are to be found not in the writings of priests and scholars but in the work of artists, travellers and sportsmen. An unknown artist, presumably a monk in the abbey at Bury St. Edmunds, painted plants in a manuscript of the *Herbarium* of Apuleius Barbarus. Although this work was done at the beginning of the twelfth century some of the pictures are accurate representations obviously made from

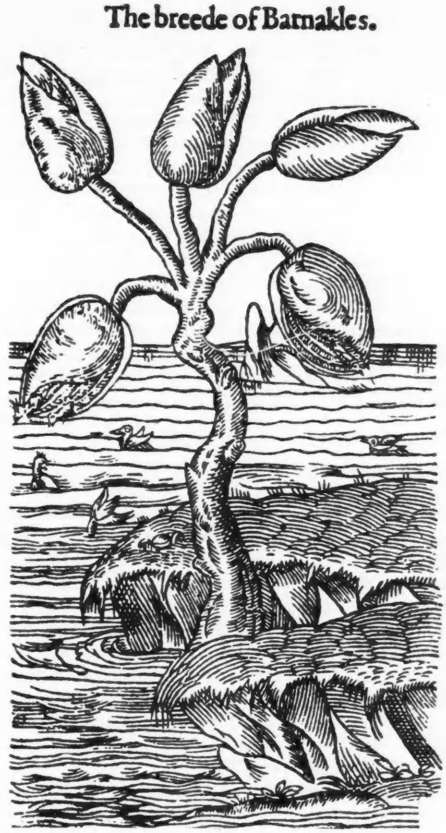
* *English Naturalists from Neckam to Ray*, by Charles E. Raven. Cambridge University Press, 1947—to which book the author of this article is indebted for his material.

living specimens. The works of Giraldus Cambrensis, although full of the traditional lore, contain many more instances of accurate first-hand observation than do those of his contemporary, Neckam. In 1251 Matthew Paris (*Chronica Majora*) accurately recorded, with illustrations, a rare immigration of crossbills. Such sports as hunting, falconry and fishing, although they had traditions of their own, remained to a large extent unaffected by those of mediaevalism, with the result that early writings of these subjects have a more modern flavour than contemporary works of a more scholarly kind. Perhaps the best example is that part of the famous *Boke of St. Albans*, printed in 1496, which is called the 'Treatyse of Fysshing'. Fishing is a practical craft whose lore was prevented from becoming legendary and false by the continual testing to which it was subjected. The 'Treatyse' is not an original work; it is the first printed account of a lore which had been accumulating over many centuries, and it is packed with sound and well-presented information with scarcely a trace of mediaeval symbolism. One of its few inaccuracies concerns the tench which "heelith all manere of other fysshe that ben hurte yf they maye come to hym"—a legend which antedates the 'Treatyse' and which was not finally exploded until the nineteenth century.

The Renaissance

The Renaissance was brought to England by five men of Oxford University. None of these can be described as a naturalist, yet one of them, Thomas Linacre, did much to serve the cause of science. During his long sojourn in Italy he came into contact with those Renaissance scholars who were later looked upon as the founders of modern natural history: Ermolao Barbaro, the Venetian, who published in 1492 a new version of Pliny's *Natural History* with over five thousand corrections; Niccolo da Lonigo who, in the same year, produced his *De Erroribus Plinii*; Aldo Manucci, the great printer of Venice, from whose press poured forth a stream of newly discovered classical texts of all kinds. Linacre took his M.D. at Padua in 1496 and in 1509 became one of the physicians to Henry VIII. In 1518 he founded the College of Physicians. His contribution to the new learning consisted in the translation of Proclus and Galen from Greek (in those days a little-known language) into Latin. His European contemporaries were similarly occupied with the works of Aristotle, Theophrastus, Dioscorides, Aetius, and many others. Thus there gradually became accessible, in accurate translation and in printed version, many ancient writings which had hitherto been available only in a hopelessly garbled form. In the field of natural history these were a great advance on the works of Neckam and Bartholomew: in other fields they exposed so many distortions in the current dogma that they brought about the Reformation.

It must be emphasised that this early phase of the Renaissance was not marked by any resurgence of the spirit of Roger Bacon. The necessity for original research and independent investigation was no more clearly recognised than it had been in mediaeval times. The change, so far as natural history is concerned, consisted in the replacement of the old authorities (the *Hexaemera*, Isidore, *Physiologus*) by new authorities who were in fact older than their predecessors. The technique remained



The belief that barnacle geese arise from goose barnacles took many centuries to kill. It was exploded in the thirteenth century, yet Gerard repeats the legend and embellishes it in his *Herball* of 1597, from which this picture is taken.

the same. Mediaeval scholars like Bartholomew had produced encyclopaedic works based on the old authorities; the first phase of the Renaissance ended in the production of similar tomes based on the new. Works of this type came to be known as 'pandects' and among them there is one by an Englishman that is worthy of notice.

Gesner and Wotton

Edward Wotton, M.D. of Padua and Oxford and President of the College of Physicians 1541-43, set out in a very ambitious way to make a compilation of all the ancient authors whose work could contribute anything of value to medicine. He had already made some progress when he encountered the books of Jean Ruel and Georgius Agricola and realised that, in the matter of plants and minerals, he had been forestalled. This caused him to concentrate on zoological and anatomical references. His work, *De Differentiis Animalium*, was ultimately printed by Michel de Vascosan of Paris in 1551. Gesner says of Wotton that "he teaches nothing new but gives a complete digest of previous works on the subject".

Best known of all the 'pandects' are the series of huge volumes published by Conrad Gesner at Zurich just after

the middle of the sixteenth century and the still larger series of Ulisse Aldrovandi some fifty years later. Gesner marks a turning-point in natural history. Medicine, to which the first phase of the Renaissance had given such an impetus, was by now beginning to make new demands. Doctors using the pharmacology of Dioscorides wanted to be sure that the plants they received from the herbalists were in fact the ones that Dioscorides specified. To meet this demand scholars had to leave their books and go out into the fields. Plants were collected; some were replanted in physic-gardens, others were placed in herbaria. Descriptions were checked against specimens, new species were discovered, drawings and paintings were made, classifications were attempted. All over Europe men were engaged in these new pursuits and Gesner, himself the possessor of a fine garden, was in touch with the best of them.

Turner's Studies

Among these correspondents of Gesner was William Turner. Turner was born at Morpeth, Northumberland, in 1508. He was probably educated in Newcastle and went up in 1526 to Pembroke Hall, Cambridge, a college which at that time had a regular connexion with Northumberland. He had his knowledge of Greek from Nicholas Ridley, a fellow Northumbrian later to be martyred with Hugh Latimer, and from Latimer he learned of Erasmus's Testament and of the writings of Martin Luther—knowledge which caused him to become a prominent member of that band of Cambridge scholars who were the pioneers of the Reformation in England.

It has become customary to regard the Reformation as a liberal and progressive rebellion against the entrenched conservatism of the Roman Church, but the early Protestants such as Turner did not regard themselves in this light. They saw themselves rather as conservatives demanding a return to the ancient faith and a rejection of Roman distortions and innovations. This type of conservatism is evident in Turner's scientific work. If he rebelled against the mediaeval authorities it was to champion the older learning of Greece and classical Rome. Wherever possible Turner consulted his authorities in the original Greek; failing this he would use the Latin versions of modern scholars such as Theodore of Gaza who had had access to the original manuscripts. By checking these versions one against the other he would endeavour to arrive at the precise meaning. The final step was to discover in the field the exact species of plant or animal to which the description was intended to refer. When this was established beyond all doubt the original description could be amplified.

Turner's first botanical work, the *Libellus de re Herbaria*, was published in London in 1538. It is little more than a glossary of 144 plants, written in Latin with Greek and English synonyms and with occasional notes concerning the uses of certain plants. Early in 1540 Turner went into exile. Leaving his wife in the Rhineland, he travelled to Italy. After a short stay at Venice, he divided his time between Ferrara and Bologna, taking his M.D. at one or other of these Universities. At Ferrara he worked under Antonio Musa Brasavola and at Bologna, then the most vigorous scientific centre in Europe, under Luca Ghini who taught him how to make a 'hortus siccus' (herbarium of dried plants). This experience put him on an equal footing with contemporary European naturalists, and if his scientific work does not compare with theirs in stature the reason lies in the amount of time he devoted to religious controversy. He returned to Germany by way of Switzerland where he made the acquaintance of the great Gesner.

At Basle, or perhaps a little later in Germany, he met Leonhardt Fuchs whose *De Historia Stirpium* was published in 1542. Turner settled down in Cologne probably until 1544 and it was here that his book on birds, *Avium praecipuarum*, was written. He then moved to East Friesland where he lived for four years, of which two were spent in preparing a Latin herbal. On his return to England about 1546 he became a physician to the Duke of Somerset and in 1548 he published, pending the completion of his Latin herbal, a list of *The Names of Herbes in Greke, Latin, Englishe, Duch and Frenche wyth the Commune Names that Herbaries and Apotecaries use*. This, like the *Libellus*, was an alphabetical list beginning with those plants described by the ancients. Following the practice of Otto von Brunfels, newly discovered plants were grouped together at the end. Turner's *Names* constitutes the earliest authentic record of over 100 British plants. In 1551 he published the first part of his *Herbal*. The arrangement here was in alphabetical order of Latin names ranging from Absinthium to Faba and only those plants listed by classical authors were included. The descriptions were in English and not in Latin as had been Turner's original intention. The work was illustrated by 169 woodcuts.

The appearance of the second part of the *Herbal* was delayed by the consequences of Somerset's downfall and the liberation of Stephen Gardiner from the Tower. Turner again fled to the Continent and took up residence in Germany. The second part, from Fagus to the end of the alphabet, was eventually published in 1562. Finally in 1568, the year of Turner's death, the complete *Herbal* was published, the work consisting of a revised version of the first part, a reprint of the second part, and a new third part devoted to plants of medicinal importance not described by the ancients.

Turner's status is not easy to assess. There is no doubt that he was the equal of most of the European scholar-naturalists of his day, giving place only to such as Gesner. Had he devoted more of his time and energies to scientific work, had he not died at the relatively early age of sixty and, above all, had he published his *Herbal* in Latin he would have achieved the recognition he deserves. As it was, the great Flemish naturalists who followed seem scarcely to have heard of him other than through Gesner. Yet, by writing his *Herbal* in English, he did more for the development of English natural history than any Latin herbal could have done. One more acknowledgment is owing to Turner. In his study of the British flora he found many plants which, although described by the ancients, had no English names. Turner obligingly translated their Latin names into English and many of these have stuck; among them Loosestrife, Goats-beard, Stone Parsley, Hawkweed and Ground Pine. (*To be concluded*).

Continued from p. 61 of previous issue.

Labelled Atoms

THE USE OF ISOTOPES IN BIOLOGY AND MEDICINE

RAYMOND GLASCOCK, B.Sc.

In the last issue the introduction of tracer techniques into the study of biological processes was described. An account was given of the use of radioactive iodine in research on the thyroid gland, and on the physiological effects of insulin. New facts about the iron economy of the blood have been obtained by studying what happens to radioactive iron fed to experimental animals. Of great interest is the American work which sheds new light on the synthesis of the blood pigment, haemoglobin.

The blood is a complex tissue consisting of a pale amber fluid called the *plasma* in which float two kinds of cells. The *red blood cells*, which owe their colour to the red respiratory pigment *haemoglobin*, are present to the extent of about five million per cubic millimetre in a healthy man. The *white blood cells* or *leucocytes* are about 500 times fewer (8,000 to 10,000 per cubic millimetre) and their function is to destroy invading bacteria and to digest dead tissue. A third kind of cell called the *blood platelets* are smaller but similar to the red blood cells and are thought to split off from them in the bone marrow. They are concerned with the clotting of blood. The plasma is a solution of proteins, glucose and salts and serves also as a vehicle for secretions and excretions.

The red pigment haemoglobin is a conjugated protein formed by the union of the iron-containing substance *haem* and the protein *globin*. It readily adds on a molecule of oxygen and by this means transports oxygen from the lungs to the tissues. Haem is a complex molecule containing an atom of iron.

Tracer Iron.—Ordinary iron consists of a mixture of four stable isotopes: Fe^{54} (6%), Fe^{56} (91·6%), Fe^{57} (2·1%) and Fe^{58} (0·28%). Of these the last and rarest, Fe^{58}, yields on deuteron bombardment the radioactive isotope Fe^{59} which decays with a half-life of 47 days; it emits β- and γ-rays.

There are two other radioactive isotopes known with mass-numbers of 53 and 55. The first has a half-life of only 9 minutes while the second, although having a half-life of 4 years, emits radiations not easily counted. 47-day iron (Fe^{59}) has been most used for tracer work.

Cruz, Hahn and Bale (1942) investigated the uptake of iron by the red blood cells of a dog. The animal was depleted of its iron reserves by repeated bleeding; this was necessary for the experiment because considerable amounts of iron are stored in tissues other than the blood. It was fed, meanwhile, on an iron-deficient diet. By the time the experiment began the red cell count had fallen from 5·5 to 4·4 million per cubic millimetre.

The dog was then fed with iron containing the radioactive isotope, the dosage being 30 milligrams of iron a day. The iron thus administered naturally improved the haemoglobin content of the blood and this is shown by the lower curve (see Fig. 5) which was obtained by the analysis of samples withdrawn from time to time. The radioactivity of the blood was also measured, and it will be seen from the upper curve that it rises in a manner almost exactly parallel with the haemoglobin content. This means that the labelled iron is being synthesised into haemoglobin.

When both the haemoglobin content and radioactivity ceased to rise (5 to 10 days after the last dose of radio-iron) a substance (pyrodin) which destroys red blood cells was injected, the doses being spread over four days. Examination of the blood showed a sharp decrease in the haemoglobin level accompanied by a parallel drop in radioactivity. This means that destruction of red cells is accompanied by destruction of haemoglobin and also that the iron is disappearing from the blood.

The iron is not excreted however: for when dosing with the pyrodin ceases, the blood recovers and both the haemoglobin *and* the radioactivity return to their former values shown in the graph. This means that the *same iron* is being used to make new haemoglobin.

This dog, however, had its iron reserves depleted by bleeding. What would happen to a normal animal? These workers carried out a similar experiment with a dog with undepleted reserves and obtained similar results. In this case, moreover, it was found that the iron in other tissues (for example, muscle haemoglobin) was not radioactive and had not therefore been involved in the process. These experiments show what rigid economy of iron occurs in the animal body: the same iron is used over and over again.

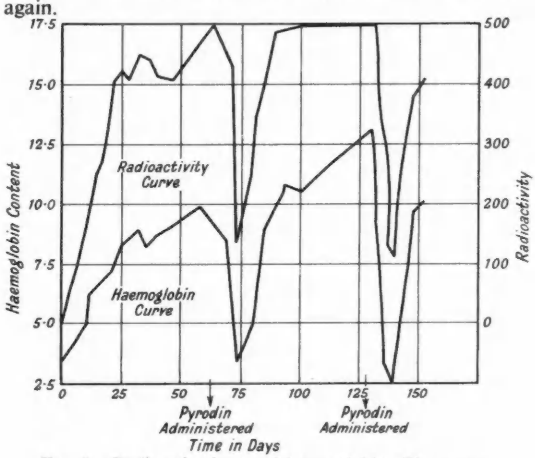


FIG. 5.—Radioactive iron and haemoglobin. The upper curve shows the variation of radioactivity of the blood after administration of radio-iron to an anaemic dog. The lower curve shows the more or less parallel variation of haemoglobin. At about the 60th day pyrodin was administered; a sharp drop in both radioactivity and haemoglobin content results.

As new haemoglobin is synthesised, as shown by the lower curve, the radioactivity of the blood also increases, indicating that the labelled iron is being built into the new haemoglobin. If unlabelled iron (e.g. from other tissues) were being used to make the haemoglobin the radioactivity would remain at the low level.

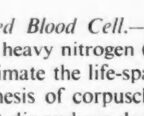
The same cycle is repeated after the 126th day.

FIG. 6.—Radioautograph of an ash cutting which has absorbed radiophosphorus. Note the greater absorption in the younger leaves. (*Courtesy of Dr. R. H. Herz of Kodak Ltd.*)

Such strict iron economy is in striking contrast with, say, that of phosphorus. It has been shown with radioactive phosphorus (P^{32}) that there is a constant exchange between tissue and diet phosphorus. That is to say a single dose of radiophosphorus will rapidly appear in the bone and then diminish as it is replaced by inactive phosphorus contained in the food.

Life of the Red Blood Cell.—Shemin and Rittenberg (1947) have used heavy nitrogen (N^{15}) in a very ingenious experiment to estimate the life-span of the red cell. There is a constant genesis of corpuscles in the long bones to replace those that die and are degraded.

One of the workers, Shemin, took 66 grams of isotopic glycine in 60 doses spread over three days. We say 'isotopic glycine' because it had been specially synthesised to contain a considerable excess of the heavy isotope of nitrogen, N^{15}. Glycine is the simplest amino acid and a constituent of proteins. It has the formula:



and in this case was labelled, as indicated, in the amino group with N^{15}.

After dosing himself Shemin collected blood samples. The haem of the blood was isolated and analysed isotopically using the mass spectrometer. The N^{15} content of the haem was plotted against time, the results being shown in the graph (Fig. 7).

This graph has a peculiar form: obviously the curve represents the lifetime of something and since we cannot imagine one molecule being different from another because it is 'older' it must be the life-span of a living thing—in this case obviously the red cell. In other words the haem molecules are synthesised from isotopic glycine and remain within the cell until its turn for degradation comes: the cells are not indiscriminately destroyed but serve an allotted span.

It is not possible to read off the life-span of the cell directly from the graph for cells are dying and being born the whole time. But if mathematical allowance is made for this in the treatment of the results the mean life-span is calculated as 127 days.

An important feature of this particular experiment needs to be emphasised. Not only may *atoms* be labelled as in the case of the experiments with radio-iodine and the thyroid, *molecules*, as in the case of tagged insulin, but also *cells*. It will be remembered that in the experiments on iodine uptake by the thyroid the workers were concerned only with the fate of iodine atoms; a derivative of insulin, on the other hand, was tagged and the whole molecule traced. In the work by Shemin and Rittenberg just described, however, it will be noted that an even more complex unit has been labelled, namely a living cell.

Estimating the Volume of Body Fluids

The use of isotopes to determine the total water in the body or the total amount of a given salt has been successfully applied by Moore. The method used is the *isotope dilution technique*. This may be explained by a simple analogy: suppose we needed to know the total volume of water in a swimming bath; 500 lb. of salt are added and, when côompletely dissolved and mixed in, a sample is withdrawn and analysed. It is found to contain 0·01 lb. salt per gallon. A simple calculation shows that 500 lb. must be contained in 50,000 gallons which is the volume of water in the bath.

Moore found that total body water could be determined using heavy water. A sample of water containing a known quantity of heavy water was administered and, previous experiments having shown that mixing with body fluids is complete after one hour, a sample of blood withdrawn after that period. Estimation of heavy water in the sample could be used to calculate the total body fluids.

Other elements have also been used for this purpose, for example radioactive potassium. In each case, however, it is necessary to know how long to wait before mixing is complete and this may vary considerably from element to element. Potassium, for example, takes about 36 hours to attain equilibrium compared with one hour for heavy water. This technique will also tell the amount of potassium in the body.

The blood volume can be estimated using this technique by labelling red cells themselves. For example radio-iron fed to one dog will appear in the red cells. These labelled cells are then transfused into another and, when mixing is

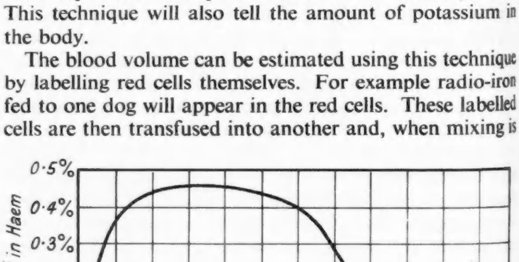


FIG. 7.—Life of the red blood corpuscle. The graph shows variation of heavy hydrogen in haem from blood of subject fed with labelled glycine. From this curve Shemin and Rittenberg calculated the mean life of the blood corpuscles as 127 days.

complete, a sample of blood withdrawn and tested. From its radioactivity—so many counts—and the number of counts transfused the blood volume can be calculated.

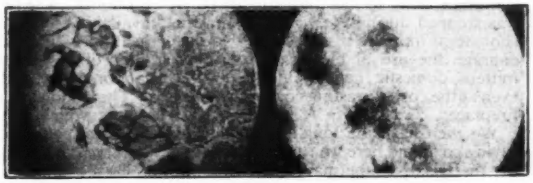
Tracers in Diagnosis

One of the most difficult conditions to diagnose is general toxaemia due, say, to a deep-seated abscess in an unknown position. Moore and Tobin (1942) suggest that tracer technique with selectively absorbed dyes might be a help in such conditions.

It is known that when certain colloidal dyes such as Trypan Blue are injected they become localised in areas of inflammation. Moore and Tobin treated the dye Trypan Blue with radioactive bromine, and thus obtained radioactive dibromo-Trypan Blue which was injected into a rabbit which had a virulent staphylococcal infection of the leg. The radioactive dye was injected intravenously over a period of about 5 hours and after the last dose the animal examined with the Geiger Counter. In normal animals injected with the dye the maximum radioactivity extended over the large zone of the liver, spleen, heart and lungs, but in the infected animal the activity in the infected leg was more than twice that in the uninfected leg.

Normal thyroid tissue. The darkened areas in the radioautograph represent the regions of the greatest accumulation of radio-iodine.

Non-toxic goitre. The cells are enlarged and distended with colloid which has accumulated very little iodine. The small cells surrounding the colloid deposits stored much more iodine.



Cancer of the thyroid. Three small islands of thyroid have not been invaded by cancer cells and from the radioautograph these are seen to have accumulated the most iodine.

FIG. 8.—Radioautographs show the regions where radio-iodine is concentrated in the thyroid. These photographs—ordinary photomicrographs on left, radioautographs of same sections on right—were made by Dr. J. G. Hamilton, and originally published in *Journal of Applied Physics* (1941, Vol. 12, page 440).

Radioautographs

While it is often sufficient to know that a given substance concentrates in a given organ, it is also sometimes valuable to know how the substance is distributed in the actual tissue of that organ. The preparation of *radioautographs* is sometimes possible and in such cases this information can be obtained (Fig. 8). Radioautography makes use of the fact that the radiations from a radio-element will affect a photographic plate. An example is provided by the experiments of Hamilton, Soley and Eichhorn (1940) who prepared radioautographs of thyroid tissue following dosage with radio-iodine. 8-day iodine was administered as sodium iodide and the thyroid operated on surgically two to three hours later. The thyroid tissue removed was cut into sections with the microtome and placed on X-ray film. After a time previously determined the sections were removed and the films developed. The same sections were afterwards stained for microscopic examination in the usual way. By examining the stained section and the picture on the film together it is possible to see the exact distribution of the radio-iodine because the radiations it had emitted had recorded themselves on the film in a pattern identical with that of the element in the section. The results of this experiment are shown in the picture.

Since Hevesy's work on the distribution of lead in the broad bean many experiments have been carried out on the distribution of elements in plants. With the exception of the more modern radioautograph technique (Fig. 6) the methods used are substantially similar to those of Hevesy's in his original experiment.

Although the most spectacular use of tracers has been in biology and medicine quite a number of interesting problems of chemical mechanism have been solved by this technique. Heavy hydrogen, for example, has been used in a large number of chemical problems. This isotope, known also as *deuterium*, has a mass twice that of the lighter and more abundant isotope and occurs to the extent of about 1 part in 5000 of ordinary hydrogen. It is stable and is unique among the isotopes in being twice as heavy as the lighter isotope: in all other cases the heavier isotope is only a fraction heavier than the light ones. (For example C^{13} is only about 8% heavier than C^{12}.) A good deal of work has been done with deuterium on the chemistry of hydrogen compounds. For example, by labelling the hydrogen atoms of a hydrocarbon chain in a fatty acid it is possible to find how the tendency to ionise varies with distance from the COOH group. This is done by finding the rate at which *exchange* takes place between the light hydrogen of a solvent and the heavy hydrogen of the compound.

Of the vast range of problems successfully tackled by the use of isotopic tracers, a few have been cited as examples in the preceding pages. It is emphasised that the experiments described are only *examples*, which have been chosen more for their suitability for exposition than for their relative importance. In no way is the article a review of the literature, although a short reading list is appended.

READING LIST

Applied Nuclear Physics, by Pollard and Davidson. (London, Chapman & Hall.) *Radioactive Tracers in Biology*, by M. D. Kamen. (Academic Press, New York). *Actions of Radiations on Living Cells*, by D. E. Lea. (Cambridge University Press.) *Why Smash Atoms*, by A. K. Solomon. (Penguin Books.) *Science News No*. 2. (Penguin Books.)

Gas, Electricity and the Nation's Coal

SIR—It is unfortunate that the protagonists of both gas and electricity (DISCOVERY, 1947, Vol. 8, p. 380) tend to argue solely about the relative thermal efficiencies of their products, for there are other factors which may be of even greater importance. Electrical energy is incomparable as a source of motive power for industry, but in the field of fuel and power the greatest national danger at the present time is the 'power cut' which robs industry of motive power because of a cold-weather increase in the use of electricity for intermittent or supplementary heating. This danger only arises because the continued growth of power-station capacity to meet growing demand was stopped during the war. Hence as a short-term measure it is necessary to discourage the use of electricity for intermittent domestic heating at all costs—even at the cost of wasting coal in the open fireplace.

We then have the long-term policy of saving coal, and here we run into the issue of the relative thermal efficiencies of different methods of heating small houses. It will be a long time before the bulk of the population is housed in buildings with high-efficiency heating systems, and the practical problem of the moment is the heating of individual rooms. If we unanimously condemn the open coal fire, the choice of regular heating of individual rooms is between the fixed gas fire and some form of electric heater. The local efficiency of the latter is 100%, and its overall efficiency (from coal input at the power station to heat in the room) about 19%. The overall efficiency of the gas fire can hardly be determined, because more than half the thermal output of the gas works is in the form of coke; without knowing the efficiency with which this coke is used, one cannot say how much heat is obtained from the coal used in running a gas fire. But if we accept the calculation that

(efficiency of gas production) = (thermal content of gas + thermal content of coke) ÷ (thermal content of coal input),

this efficiency is about 70%. The overall efficiency of the fixed gas fire is then about 30%, according to the protagonists of gas heating—appreciably more efficient than electric heating, but not twice as efficient. As an alternative approach, Mr. Schiller quotes the Building Research Board's Committee on Heating and Ventilation as an authority for taking 1 therm of gas equivalent to 11 kWh. of electrical energy for space heating or 14 kWh. for cooking. On the gas-efficiency formula shown above, 1 therm of gas corresponds to 18 lb. of coal; and 11 and 14 kWh. of electrical energy correspond to 18 and 24 lb. of coal, respectively. I suggest that all told the most probable figure for the superiority in thermal efficiency of gas over electricity for domestic heating is between 1¼ and 1½ to 1, which is not overwhelming.

But, says Dr. Foxwell, electricity is used for many other purposes besides room heating, where the efficiency may be lower. Yes, and the many other purposes in the home include the radio and the vacuum cleaner, for which gas is a non-starter, and ensure that electricity will be demanded in every home. It then seems an unnecessary complication to bring in also a gas supply when electricity is already there and capable of doing everything that is wanted. This attitude is encouraged by the greater ease of distribution of electricity, which results in country houses frequently having a main electricity supply but no gas. (You cannot really expect people to bother with cylinders of butane, in the interests of coal economy, when there is electric power available.) On the other hand, water-heating is the domestic service for which gas probably gives the best combination of labour-saving and fuel economy.

The following, then, are some of the points which must be considered when formulating a fuel policy for the householder:

(1) For the next few years, 'power cuts' in cold weather can only be avoided by the self-denial of the domestic consumer, the encouragement of gas fires in homes which are already equipped with a gas supply, and the use of the open coal fire in spite of its dirt and inefficiency.

(2) The main complaint against the electric heater is that the electric power station wastes low-temperature exhaust heat in cooling towers or in heating-up the nearest river. A more determined effort must be made to find use for this exhaust heat, even if it involves some modification to the main power plant.

(3) If any 'fuel-less' sources of power are developed, such as atomic energy, hydro-electric or tidal energy, its distribution will be via electrical systems and appliances. 'Coal economy' will then mean using less gas, and more electricity.

(4) The "efficiency" of coal gas cannot be separately determined but depends on the use which is made of the associated coke. The size of the gas industry should, therefore, depend on the extent to which efficient use can be found for coke.

(5) Rising standards of living of the poorer part of the population means an increased demand for labour-saving methods in the home. This tends to exclude the use of solid fuels, including coke.

D. A. BELL.

The Bookshelf

Man's Last Choice. A Survey of Political Creeds and Scientific Realities. By E. M. Friedwald. (Heinemann, London; Viking Press, N. York, 1948; pp. 144, *8s. 6d.*)

THERE is much in this book that is well known, but all of it is worth saying again and again. For there is still no indication that the significance of the well-known facts that the author has marshalled has been grasped. Quite recently we had a full-scale debate on foreign affairs at Westminster, with the atomic bomb being hardly mentioned. The facts of atomic power must be drummed into the public conscience unrelentingly if we are to act as responsible men in the face of what Mr. Friedwald well calls "man's last choice".

Mr. Friedwald writes in a calm and carefully formulated manner, yet it is difficult to quote his facts without making them sound alarmist, for these facts are unfortunately so much beyond the power of our imagination that they sound unbalanced and hysterical.

To me, the main points are these: As yet extensive production of atomic bombs has been going on only in the United States. Eighteen months after Hiroshima, production was estimated at only about half a dozen bombs per month, but there is every reason to suppose that production up to a few hundred or even a thousand bombs a year may be well on the way. There is every reason to expect that within a few years' time Russia also will be able to produce bombs on a similar scale. Now, atomic bombs are, in Mr. Friedwald's term, 'saturation' weapons; that is, you require a certain number of them to put out of action a particular country with which you are at war, and there is no purpose in having more bombs than that number. Britain could be saturated by, say, 200 atomic bombs; the United States could be destroyed by less than a thousand bombs, whereas Russia could probably be devastated by a few thousand bombs. It may not be a much more difficult or longer job to drop 2000 than 200 atomic bombs. It follows that while the United States have an overwhelming superiority in the possession of a greater number of atomic bombs at present, they will lose their supremacy as soon as Russia has made enough bombs to 'saturate' the United States. There would be no decisive advantage to America in having ten times as many bombs at that stage. The superiority would lie entirely with the side which could make more extensive secret preparations, both within their own country and by infiltration and planting of bombs in the opponent's country, and which, empowered by a philosophy which justifies the merciless pulverisation of its opponent, could act dictatorially, without consulting its own public opinion. It is obvious that all these and other important advantages—such as a larger and more widely dispersed population—would be with Russia, which in consequence would gain definite superiority at that stage.

Mr. Friedwald advocates international atomic control and argues that Russia herself should be prepared to make a sacrifice of sovereignty in the interest of her own preservation. But this point is

far from clear, for he seems to admit—and it is certainly true—that the Soviet Government would have little chance of surviving the submission of its country to an effective international inspection armed by swift powers of coercion to punish and suppress any attempt at elusion. In fact the Soviet Government is quite right in affirming that this would mean surrender of ultimate power over its country to a body of 'capitalist' representatives associated in effect with the United States as the supreme power over the planet.

Failing the acceptance of international control by the Soviets, Mr. Friedwald advocates that the nine-tenths of humanity outside the Soviet Union should make a start with World Government and atomic control. But this suggestion seems to me empty of content, for the suggested World Government would leave the present situation unchanged. There would still be the United States and Soviet Russia engaged in a race in which Soviet Russia is bound to win, as soon as she reaches the power to 'saturate' the United States. Any constitutional functions the World Government would exercise could only slow down further the unwieldy machineries of democracy in their reactions to the possibility of a Russian attack, and thus increase the superiority of Russia's secret and dictatorial swiftness.

However, we must not expect Mr. Friedwald to find a solution to this problem, and we must be grateful to him for pressing us hard to realise the facts, for that may at least give us a chance to do some reasonable thinking on the questions which he leaves unsolved.

M. Polanyi.

Electrons (+ and −), Protons, Photons, Neutrons, Mesotrons, and Cosmic Rays. By R. A. Millikan. Revised Edn. (University of Chicago Press; Cambridge University Press, 1947; pp. 642, 30*s*.)

In 1935 Prof. Millikan made the mistake, as some think, of expanding his classic *The Electron* of 1917 into a volume which reflected both later discoveries and his own current interests, the title being at the same time expanded to include all those particles now listed except the meson. The present edition includes new chapters both on the latter and on the release and utilisation of atomic energy. Its most individual quality, however, apart from the author's charm and persuasiveness of writing, is the up-to-date presentation which it affords of the atom-annihilation hypothesis of the origin of cosmic radiation—on which, as is well known, Prof. Millikan appears frankly as protagonist.

Plastics. By N. J. L. Megson. (Published for the British Council by Longmans Green, London, 1947; pp. 45 + 17 illustrations, 1*s*. 6*d*.)

This essay, by a well-known expert in the field of synthetic resins, is described as "a short account of developments, applications and potentialities of synthetic high polymers". Its introduction declares its main purpose to be "to indicate how far Great Britain has been responsible for advances in the industry", and the emphasis is therefore on British work. Nevertheless the balance of the account is well preserved.

The work does not pretend to be a complete account, nor even a comprehensive summary of developments. It is rather an essay on some of the more important (British) developments, preceded by a brief historical survey, with a thumbnail sketch of the organisation of the Plastics Industry in Britain for the penultimate chapter.

For a popular account, the text is pleasingly accurate from the scientific point of view, although there are a few typographical errors, mostly in the titles of the illustrations. Within the limitations imposed by its declared scope and purpose, this essay is an interesting contribution to the series of British Council booklets dealing with various aspects of science and technology.

Magnesium Fabrication. By Lothair B. Harkins. (Pitman, New York and London, 1947; pp. 146, 20*s*.)

This American book covers the working-up of sheet and extruded magnesium alloys into final form by pressing, riveting, welding and machining. It does not deal with sand- or diecasting, sheet-rolling or extrusion. The alloys described are all of American specification.

Covering a considerable range at the expense of depth results in a cataloguing of techniques, of little use to the scientific worker, and in insufficient detail for the practical man. It may give the business executive, however, a view both wide and deep enough for his purposes; to two large American producers, who contribute 31 of 33 photographs, it provides considerable advertisement. It is not up to the standard of the works produced by its English publishers under their own imprint.

The Rare Earth Elements and Their Compounds. By D. M. Yost, H. Russell and C. S. Garner. (Chapman & Hall, London, 1947; pp. 92, 15*s*.)

This monograph contains a useful compilation of recent work on the physical properties of the rare earth elements, in particular their electronic structure, magnetic susceptibilities and absorption spectra. On the chemical side the treatment is not as systematic as it might be, and no mention is made of recent British work which has provided a new and extremely effective method of separation of certain of the elements. In the absence of a more complete work, however, this book will be a useful addition to the reference library.

Far and Near

$90 million for Atomic Research

A broad programme of atomic research as developed during the past year, was outlined by the U.S. Atomic Energy Commission in its third semi-annual report to Congress, made public on February 2. The report noted the inauguration of a 90-million-dollar project for new research facilities, and co-operation with 200 organisations.

The Commission reported that the paramount objectives of "assuring the common defence and security" as defined in the Atomic Energy Act of 1946 required a major programme of development at the Los Alamos scientific laboratory where the weapons programme is concentrated.

The report recalled the plans announced by President Truman last September to share radio-isotopes for research with other nations, and revealed that at the end of 1947 shipments have been made to users in Argentine, Australia, Denmark and the United Kingdom. "To date, as a result of requests received," the report states, "the Commission has approved future distribution to Belgium, Canada, Cuba, France, Ireland, Italy, the Netherlands, New Zealand, Peru, Sweden and the Union of South Africa."

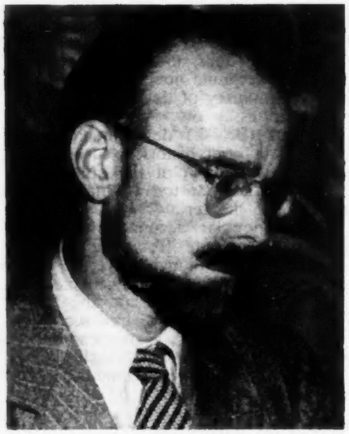
The report said that the production of fissionable materials was maintained throughout the year and a general programme for expansion of capacity was started along four main lines. These were through development of new sources of raw materials, improvement of processes for the reduction of ores, renovation and expansion of facilities for the production of fissionable materials, and development of the nuclear reactor for more efficient utilisation of available fissionable material.

Operational Research and the Textile Industry

In the course of a recent speech at Letchworth, the Lord President of the Council, Mr. Herbert Morrison, spoke of the importance of operational research and referred specifically to the studies made in the textile industry by the Shirley Institute of the British Cotton Industry Research Association. The Institute has come to study not only the technology of the industry, but also the economic effects of changes in processes and means of increasing output.

A simple but powerful weapon with which to attack questions of productivity is to compare the outputs of different mills (or corresponding rooms in different mills) making comparable products. The Shirley Institute collected figures for amounts of cotton processed, numbers of workers, hours worked, types of plant, and so on, over a large number of mills; from the material collected they were able to show that, for the same process and the same count of yarn, the number of man hours required per pound processed varied markedly from mill to mill, often by as much as 3 to 1. Moreover, by studying some of the apparently best and some of the apparently worst mills for any process, a good idea could be obtained of the *reasons* for the differences—practice in labour deployment, package size, layout, etc. "Their figures suggest that by bringing the practices of all mills up to

Dr. N. Howard Jones



Prof. Pierre Auger

those of the best rooms at present, a considerable increase in output, not less than 10% and possibly as high as 40%, might be obtained from the present labour force and machinery," said Mr. Morrison.

Mr. Morrison spoke of the Government's aim to secure better distribution of scientific institutions over the country. It had already been arranged that the biggest of the new research stations, the Mechanical Engineering Station, should be located in Scotland. The Government had decided that the new town at Stevenage will be given preference in considering the sites of new scientific establishments in the London region, an important point, because a number of research stations would have to move from their present sites which they had outgrown.

British Council Loses Science Director

Dr. N. Howard Jones has resigned from the directorship of the Medical Department of the British Council and the editorship of the *British Medical Bulletin* on his appointment as Chief Medical Editor to the World Health Organisation (Interim Commission). During the past two years, Dr. Howard Jones combined with his other duties that of the administration of the Science Group of Departments. This responsibility will temporarily devolve upon Mr. H. R. Mills, M.Sc.

Dr. Needham leaves Unesco

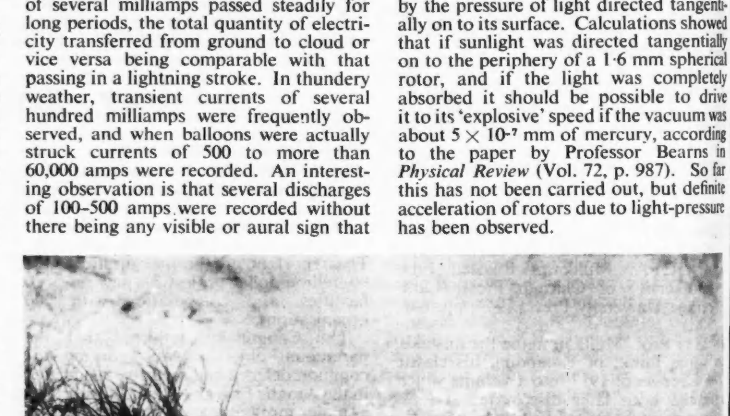
Professor Pierre Auger, a leading French scientist and member of the French Atomic Energy Commission, has been nominated head of the Natural Sciences Section of Unesco. He will replace Dr. Joseph Needham, who after nearly two years' service with Unesco is returning to his post at Cambridge University.

Currents in Balloon Cables

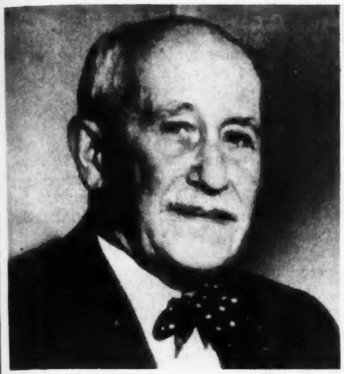
The problem of protecting barrage balloons from destruction by lightning was investigated during the war by British scientists who made measurements of the currents flowing in the balloon cables. Small currents of the order of microampères were always found to occur whatever the state of the weather. In cloudy conditions but without thunder, currents of several milliamps passed steadily for long periods, the total quantity of electricity transferred from ground to cloud or vice versa being comparable with that passing in a lightning stroke. In thundery weather, transient currents of several hundred milliamps were frequently observed, and when balloons were actually struck currents of 500 to more than 60,000 amps were recorded. An interesting observation is that several discharges of 100–500 amps were recorded without there being any visible or aural sign that the balloon had been struck. Some protection was achieved by mounting a spike of metal about 3 metres long on the nose of the balloon, but complete protection could not be hoped for, as on two occasions the flying cable was 'demetalised'—the steel sheath being vaporised by the current so quickly that the hemp core was not even scorched. Full details of these investigations are to be found in the *Proceedings of the Royal Society*, A, 1947, Vol. 191, p. 304.

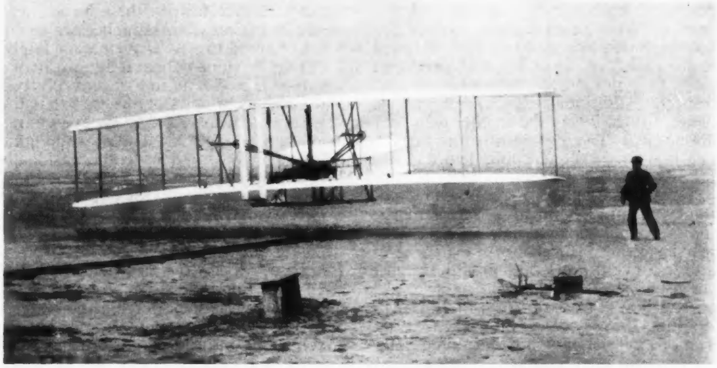
A Rotor Driven by Light?

Professor J. W. Bearns, of the University of Virginia, has for many years been engaged in achieving higher and higher centrifugal fields by spinning small rotors suspended freely in a magnetic field. He has been able to spin small rotors so rapidly that they have exploded owing to the enormous centrifugal force developed. In some recent experiments in which rotors were spun in an evacuated chamber it was found that the friction, which is solely due to the remaining gas molecules, was so slight that a sphere spinning at 100,000 revolutions per second and left to 'coast' for an hour lost only 0·1% of its rotational speed. This suggested that it should be possible to drive a rotor in such a system by the pressure of light directed tangentially on to its surface. Calculations showed that if sunlight was directed tangentially on to the periphery of a 1·6 mm spherical rotor, and if the light was completely absorbed it should be possible to drive it to its 'explosive' speed if the vacuum was about 5×10^{-7} mm of mercury, according to the paper by Professor Bearns in *Physical Review* (Vol. 72, p. 987). So far this has not been carried out, but definite acceleration of rotors due to light-pressure has been observed.



For the first time for over a century the avocet is breeding in Britain. In 1946 a pair of avocets nested in East Anglia, but the eggs were taken by a collector. Last year two small nesting colonies were observed in the same region, and sixteen young birds are reported to have been reared. In line with the appeal of the Royal Society for the Protection of Birds to the public to give the birds a chance and not to try to find out where they breed, we are withholding more exact information in our possession about the nesting sites. (*Photograph by Ian Thomson, F.R.P.S., M.B.O.U.*)





Orville Wright died on January 31 *at the age of* 76. *The photograph on right, taken on December* 17, 1903, *and reproduced by courtesy of the Director of The Science Museum, shows the first flight of the Kitty Hawk—the first flight ever made in a powered aeroplane. Orville Wright is piloting it, his brother Wilbur is seen alongside the plane. The Kitty Hawk was wrecked after its fourth flight, when it flew* 852 *ft. in* 59 *seconds against a strong wind, and it was not rebuilt until* 1928. *It was then lent to London's Science Museum. An exact replica will replace the machine after it has been sent back to America where it will be given the place of honour among the aeronautical exhibits in the Smithsonian Institution, Washington.*

Night Sky in April

The Moon—New moon occurs on April 9d 13h 16m, U.T., and full moon on April 23d 13h 28m. The following conjunctions with the moon take place;

April

7d 18h	Mercury in conjunction with the moon,	Mercury 2° N.
13d 08h	Venus	Venus 1 N.
18d 02h	Saturn	Saturn 4 S.
18d 10h	Mars	Mars 3 S.
27d 18h	Jupiter	Jupiter 4° N.

The Planets.—Mercury is unfavourably placed for observation during April. Venus is an evening star, setting at 22h 56m, 23h 28m, and 23h 45m, at the beginning, middle and end of the month, respectively, and is prominent in the western sky. Mars is visible until the early morning hours, setting at 4h 25m, 3h 23m, and 2h 41m, on April 1, 15, and 30. Jupiter, in the constellation of Sagittarius, is not visible until the early morning hours, rising at 1h 24m, 0h 30m, and 23h 30m on those dates. Saturn is visible until the morning hours, setting at 4h 07m on April 1 and 2h 13m on April 30; the planet is stationary on April 17.

There is a partial eclipse of the moon on April 23 but it will not be visible in the British Isles. It will be visible over parts of Asia and the Indian Ocean, the Pacific, Australia and the Antarctic regions.

A shower of meteors takes place from April 18 to 24; this shower is known as the Lyrids because the radiant lies near the constellation of Lyra—actually a little west of it. The meteors are caused by the earth colliding with the debris of Comet 1861I, the small particles composing this debris being heated to incandescence by friction with the atmosphere. They are rapidly dissipated by the intense heat generated and disappear in a few seconds.

A New Cosmic Ray Laboratory

A NEW high-altitude laboratory for cosmic ray research was opened by the Italian Centre for Research in Nuclear Studies on January 11. The laboratory, which is sited at 11,500 ft. on the upper slopes of Monte Rosa, on the Italo-Swiss frontier, is the highest laboratory in the world.

The station is equipped for two-way direct radio contact with the parent laboratory at Rome, a useful facility at all times, but particularly necessary when the laboratory is likely to be cut off from the outside world for days at a time in midwinter. It is served by a cable railway, which—under normal weather conditions—regularly runs from Breuil (Cervinia) in the valley, 4,500 feet below. Breuil is itself connected with the rail-head at Chatillon by a road which is kept open the whole winter. The problems of supply are, therefore, very much less than might reasonably be expected at such an altitude. At present there is living accommodation for four workers. The building itself is of aluminium and cork construction, and is securely anchored against the high winds which sweep the ridge.

The work at present going on in the laboratory includes the exposure of nuclear plates, which in suitable weather can also be carried out up to 3,000 feet above the laboratory. Experiments on meson decay are also being carried on, and it is expected that later some Italian geneticists will be undertaking work at the station on mutations induced by cosmic rays. The director of the laboratory is Prof. Gilberto Bernadini, who, together with the director of the Centre of Research in Nuclear Studies, Prof. Edoardo Amaldi, is already very well known in England for his work in this field. It is expected that at least one British physicist will be working at the station in the near future.

Britain's Scientific War Effort

A SEMI-POPULAR and illustrated account of some aspects of Britain's scientific war effort has been published at 2*s*. 6*d*. by the Stationery Office. Commissioned by the DSIR and entitled *Science at War*, it has been written jointly by J. G. Crowther and Professor R. Whiddington, F.R.S., and covers the story of the British contribution to the atomic bomb project, radar, science in the naval war and operational research.

Science Writers widen Membership

THE Association of British Science Writers is now open to accept Associate Members. Associate Membership is intended for the non-professional science writer, that is, those who do not earn the major part of their income from science writing. Those interested should apply for particulars to Maurice Goldsmith, Honorary Secretary, at 81, Hillside Gardens, Edgware, Middlesex.

Three Films on Heat

Conduction, *Convection* and *Radiation*, made by Realist Film Unit for the British Gas Association, are three excellent classroom films which will be welcomed by all teachers of the 11- and 12-year-olds. For once it would seem that sponsors and directors have given the educational adviser a free hand. The result is something new and stimulating in science-teaching films. The ground covered is what is usually called Middle School Heat, and the scope is indicated by the titles. Some usual and some unusual experiments are included in the films with great success.

The most commendable feature of these films is the slow pace of the commentary; the producers have not been afraid to leave a little breathing space where the film can actually be looked at untroubled by voice or musical accompaniment. In other words they have been satisfied to let the film do its own work visually. The teacher is thus allowed to interpose a word here and there if he feels like it, and to keep the lesson a personal thing.

The various teaching points are dealt with in separate sections of the film and followed by blanks. During these the projector can be switched off and the

points driven home by question and discussion. This novel feature enables the teacher to suit the speed of the treatment to the ability of the class. It is somewhat akin to Film Strip technique in this respect. Additional experiments can be demonstrated where the teacher feels they are needed. The film becomes a real aid, just like any other teaching device, to be used as the teacher wishes.

The very complete lesson notes include the commentary and a summary of the films. They are a great help to the teacher in suggesting introductory experiments and 'follow up' work, and greatly increase the usefulness of the films.

And now for a word of criticism. The questions posed at the end of some of the sections of the film are not quite satisfactory. Other factors than those mentioned in the previous sequence are sometimes required to answer them completely. This may be done deliberately to provoke discussion, and it is not an entirely bad feature as it brings out the fact that the film cannot be expected to do everything. The use of models in the film, while quite effective in general, does tend occasionally to give the idea that some of the experiments are 'wangled'. It is important that a film should not give away its illusions. In the convection film the candle in the fireplace provokes such remarks from a form as "Ah, it's a doll's house!"—thus taking the mind off the main point which at that time was the draughts and convection currents. But this should not be taken as serious criticism of the main idea and execution of the films which have already been of great use to the writer. Let us welcome gratefully something new, original, and effective, and award these films nine out of a possible ten!

J. P. STEPHENSON.

(The production team which made these three films comprised Alex Strasser, Dorothy Grayson, Denys Parsons and George Bennel. This review is contributed by arrangement with the Scientific Film Association.)

Correction

IN the first part of the article 'Labelled Atoms' (p. 58), paragraph 'Stable Isotopes', line 7, read '6 orbital electrons' instead of '12 orbital electrons'.

JUNIOR SCIENCE

How the Eye Works—II

LAST month I compared the retina, or sensitive part, of the eye to a photographic film—a film which can deal with an unlimited number of pictures, and is always renewing itself after each 'exposure'. If we turn now to other parts of the eye we find other points of comparison with a camera. The most obvious is the lens (look at the diagram). The lens enables you to get a well-defined image of an object focused on the retina. You can see how a lens works with an ordinary hand magnifying-glass. In a room lighted by a naked electric bulb hold the magnifying-glass over a piece of paper, and move it until you get an accurate image of the bulb on the paper. In the same way, in a camera, you vary the focus by moving the lens nearer or farther away from the film.

In the eye the lens is just behind the pupil. The pupil is the part that looks black, in the middle of the eye, and is surrounded by the coloured iris. Really it is a hole in the iris, and light enters the eye through it. The light passes through a transparent jelly (the vitreous humor) and then through the lens; then it goes through some more jelly (the aqueous humor), and finally reaches the retina.

Now how do you focus with the lens? If the comparison with the camera were exact, we should alter the distance of the lens from the back of the eye; but we cannot do that: if we did, our eyes would bulge out every time we looked at something close to us, such as this page of DISCOVERY. Actually, change of focus in our eyes is made by a change in the shape of the lens. There is a special muscle that does this (automatically, without our thinking about it), by pulling on a ligament that connects it to the lens.

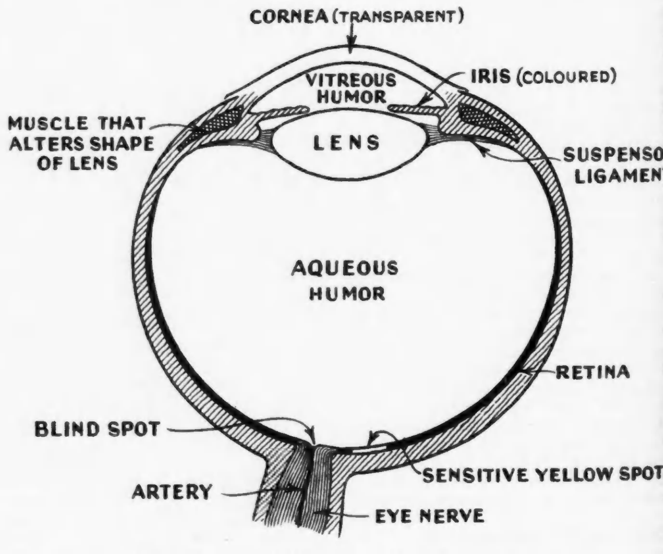
There is another automatic action that takes place in the eye—one that you can easily observe for yourself. All you have to do is shine a torch in somebody's eye and watch the pupil when you do it. (Hold the torch to one side of the face.) You can try it on yourself, and watch the result in a mirror. You will see that the pupil contracts: that is, the hole gets smaller. In general, the brighter the light, the smaller is the pupil. In a dim light, of course, the pupil opens as wide as possible. You can see this effect very well in a cat's eyes: in bright sunlight the pupil is reduced to a narrow slit, instead of a small round hole as it is in us.

In a camera you have a similar arrangement, usually just behind the lens. It is called the iris diaphragm, or the stop. In a bright light you partly close it, or 'stop down' as the photographers say. This prevents too much light getting to the film, and also increases the number of things you can have in focus at the same time: that is, it increases the 'depth of focus'. The contraction of the pupil has just the same effect on the eye.

I said that in a dim light the pupil opens as wide as it can. But this is not the only way in which the eye adjusts itself to a dim light. There are also changes in the retina. These changes are chemical ones, and take place comparatively slowly. If you go from a brightly lighted room into starlight it will take you a minute or so to get fairly well adapted, but your vision will continue to improve for something like half an hour.

The great adaptability of the eye to different amounts of light causes some odd effects. For instance, if you see a lighted candle in bright sunlight it seems to be giving no light at all. Yet in a dark room you could read by its light. The point is, your eyes are adapted to the bright light, and can hardly detect the candle light. The idea that sunlight puts a fire out is due to the same thing: a fire gives off only a little light, and if your eye is adapted to sunlight, it cannot detect firelight.

ANTHONY BARNETT.



This is a diagram of what you would see if you cut a very thin slice through the middle of the eye, from front to back.

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